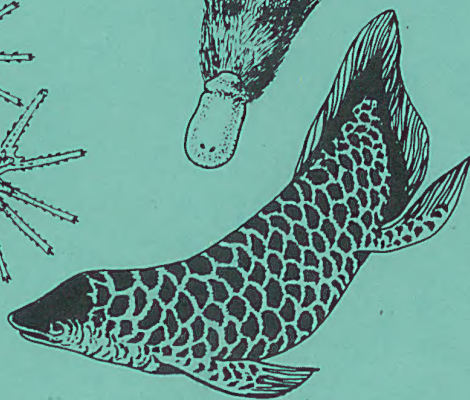
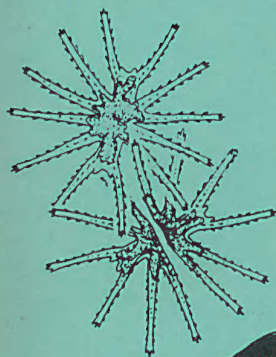
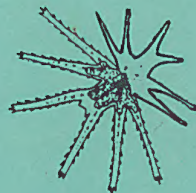
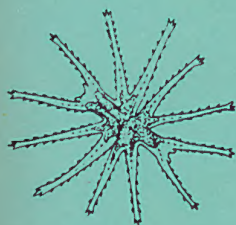


NATIONAL MUSEUM
- 4 JAN 1972
OF VICTORIA

Australian Society for Limnology



BULLETIN
No. 4

The views expressed in this Bulletin by authors
are not necessarily those of the Society or its
Editorial Board.

NOTES TO AUTHORS

In addition to publishing papers (or abstracts or titles thereof) read at the Annual Congress of the Society, the *Bulletin* will accept for publication *original contributions*, subject to the following conditions:

1. Papers not directly related to Australia, New Zealand and New Guinea may not be accepted.
2. Taxonomic papers which describe new species will not be accepted unless any "type" material has been deposited at an Australian museum and evidence is presented of its Registration.
3. Manuscripts are to be typed, double-spaced and submitted in duplicate.
4. Photographs will be accepted only in exceptional circumstances.
5. Line drawings, graphs, etc., must be kept to a minimum.
6. All papers will be subject to refereeing.
7. Abbreviated titles of journals cited in "References" must conform with the *World List of Scientific Periodicals* abbreviations.
8. 25 reprints will be made available to the author free; additional reprints will be provided at cost.



AUSTRALIAN SOCIETY FOR LIMNOLOGY

BULLETIN No. 4.

DECEMBER 1971

CONTENTS

- Page 1 Papers, abstracts and titles of papers presented at the Tenth Annual Congress of the Australian Society for Limnology, Hobart, Tasmania, February, 1971.
- Page 22 Abstracts and titles of papers presented at a "Pollution Symposium" held in association with the Australian Conservation Foundation and the Tasmanian Conservation Trust.
- Page 23 Original Contributions

TENTH ANNUAL CONGRESS

THE FOLLOWING ARE PAPERS, ABSTRACTS OR TITLES OF PAPERS, PRESENTED AT THE TENTH ANNUAL CONGRESS OF THE AUSTRALIAN SOCIETY FOR LIMNOLOGY, HELD AT HOBART, TASMANIA, IN FEBRUARY 1971.

GUEST SPEAKER'S ADDRESS

HISTORY OF TASMANIAN LAKES

(Recorded here by title only)

by J. L. Davies

*Department of Geography, University of Tasmania,
Box 252C, G.P.O., Hobart, Tasmania. 7001*

GENERAL LIMNOLOGY

BENTHOS OF THREE MAARS NEAR CAMPERDOWN, VICTORIA

(Recorded here by title only)

by B. V. Timms

*Department of Zoology, Monash University,
Clayton, Victoria. 3168*

PRELIMINARY ASPECTS OF THE LIMNOLOGY OF MACQUARIE ISLAND

(Recorded here by title only)

by P. A. Tyler

*Department of Botany, University of Tasmania,
Box 252C, G.P.O., Hobart, Tasmania. 7001*

PHYTOPLANKTON STUDIES

PRODUCTIVITY STUDIES ON LAKES SORELL AND CRESCENT, TASMANIA

(Abstract only)

by D.M.H. Cheng

*Department of Botany, University of Tasmania,
Box 252C, G.P.O., Hobart, Tasmania. 7001*

The productivities of Lakes Sorell and Crescent were measured monthly under both natural and artificial light regimes. Considerable seasonal fluctuations were recorded and the production rates were found to be much higher in Lake Crescent under both light conditions. Table 1 summarises the results.

TABLE 1
MINIMUM AND MAXIMUM OF PRODUCTIVITY MEASUREMENTS
RECORDED FOR LAKES SORELL AND CRESCENT, 1969-1971.

<i>in situ productivity</i> <i>mg C/m²/day</i>			
	No. 4-weekly measurements	Lake Sorell	L. Crescent
Minimum recorded	13	35	110
Maximum recorded	13	140	1100
Saturated light productivity mg C/m³/hour			
	No. 4-weekly measurements	Lake Sorell	L. Crescent
Minimum recorded	18	1	15
Maximum recorded	18	26	140

Production *in situ* is strongly influenced by the turbidity of the waters. There is no significant production at depths exceeding 2 metres in Lake Sorell, and 1 metre in Lake Crescent.

Short term (3 hour) enrichment experiments revealed that phosphate consistently stimulates carbon uptake in both lakes and is probably the most important immediate limiting factor, though nitrate and micronutrients showed stimulatory effects in some experiments.

Laboratory cultural experiments showed that phosphate and nitrate directly limit the size of the standing algal crop. Proportional amounts of biomass (expressed as chlorophyll *a*) are produced by adding varying amounts of phosphate and nitrate to the natural waters.

It appears that the two waters contain optimal concentrations of other nutrients apart from phosphate and nitrate. However, evidence exists that removal of suspended particles from the two waters prevents growth even in the presence of optimal phosphate and nitrate concentrations. That these particulate matters are sources of micronutrients and organic matter is demonstrated by the fact that addition of micronutrients restores algal growth to the centrifuged waters, with the growth being further enhanced by addition of chelators.

It is postulated that organic chelators, which occur naturally in the waters, hold the key to the fertility of these two lakes. The lakes are probably equal in their inorganic nutrient contents, with the upper limits of the sizes of their standing crops being set by the low concentrations of phosphate and nitrate present. However, the actual growth rates below the upper limits are strongly influenced by the presence of organic chelators and hence the availability of micronutrients, which are generally insoluble in these lakes due to their oxidised nature. Much higher organic matter concentrations are present in Lake Crescent, representing contributions from the high standing crop and from the marsh vegetation which dies and rots in winter, facilitating the utilisation of micronutrients by the Lake Crescent algae. This difference in organic matter concentrations largely accounts for the observed differences in phytoplankton between the two lakes.

SEE: Cheng, D.M.H. (1970). Lakes Sorell and Crescent: a phycological enigma. *Aust. Soc. Limnol Bull.* No. 3: 20-21.

TAXONOMIC IMPLICATIONS OF SEXUAL REPRODUCTION IN SOME DESMIDS

(Abstract only)

by H.U. Ling

*Department of Botany, University of Tasmania,
Box 252C, G.P.O., Hobart, Tasmania. 7001*

Heterothallic strains of *Pleurotaenium trabecula* var. *mediolaeae* (Playf.) Krieger, and *Pleurotaenium ehrenbergii* (Breb.) de Bary were studied in pure culture. The two taxa differed significantly only in the number of apical tubercles so far as their vegetative morphology was concerned. However, significant differences were evident in the conjugation process.

Time-lapse photomicrographs of the conjugation process in both taxa showed formation of conjugation vesicles, papillae, rapid gametogamy, contractile vacuoles, anomalous conjugations, and mature zygospores.

A unique feature of the *Pleurotaenium* zygospore was described — a morphologically differentiated operculum.

Sexual reproduction in *Staurostrum orbiculare* var. *Ralfsii* W. & G. S. West, was also described. Clones were heterothallic, producing spiny zygospores. Two germlings of opposite mating type were produced by each zygospore.

In this taxon 4-radial cells arose spontaneously in normal 3-radial clones. These variants were fully fertile, crossing with the normal 3-radials. Analysis of the products of these zygotes showed that this character was not transmitted sexually.

The taxonomic implications of sexual reproduction in desmids was discussed.

INVERTEBRATE STUDIES

COMMENTS ON MEDUSAE FROM INLAND WATERS AND ESTUARIES WITH REFERENCE TO A RECENT FIND IN AUSTRALIA

by I.A.E. Bayly

Department of Zoology, Monash University,
Clayton, Victoria, 3168.

INTRODUCTION

Although a few fairly euryhaline brackish-water Scyphozoa and Anthozoa exist, euryhaline cnidarians are largely restricted to the class Hydrozoa. Truly freshwater cnidarians are entirely restricted to this class. The distribution within the Hydrozoa of taxa that are not of a marine stenohaline nature may be summarized as follows:

- (1) Order Gymnoblastera (predominantly marine)
Family Hydridae (freshwater, widely distributed) e.g. *Hydra*
Family Clavidae (almost entirely marine but including the widespread *Cordylophora caspia* (= *lacustris*) which is euryhaline, occurring in brackish and fresh water, and even some inland saline waters)
- (2) Order Narcomedusae (almost entirely marine, but including *Polypodium hydriforme* a single aberrant species which is parasitic and occurs in northern hemisphere brackish water)
- (3) Order Limnomedusae (marine, brackish-water and fresh-water)
Family Moerisiidae

<i>Halmomises</i> (= <i>Moerisia</i>)	)	Primarily northern hemisphere
<i>Odesessia</i>	)	euryhaline brackish-water
<i>Ostromovia</i>	)	forms

Family Olindiidae
Craspedacusta (widely distributed in fresh waters)
Limnocnida (a freshwater genus found in Africa and India)
Plus two marine genera

?[?Family Australomedusidae]
Australomedusa baylii Russell 1970 (a euryhaline form found in brackish-water lagoons and coastal salt lakes in south-east Australia)

The order Limnomedusae is of considerable interest for two reasons. Firstly, although clearly of marine origin, it shows marked euryhaline tendencies and the ability to colonize inland waters. Secondly, except for *Craspedacusta*, its non-marine representatives tend to have localized distributions and are thus of zoogeographical interest.

The Discovery of *Australomedusa* — a new limnomedusan

In December 1969 a small medusa was collected from a salt lake located between Beachport and Robe in South Australia. This proved to be a new species and genus which has been described by Russell (1970) under the name *Australomedusa baylii*. The taxonomic position of this genus cannot be decided for certain until its hydroid stage, which is almost certainly minute, is discovered. However, Russell thinks it probable that it belongs to a new family within the Limnomedusae. *Australomedusa* agrees in several respects with the Moerisiidae but differs from all previously described limnomedusans in possessing multitentacular marginal bulbs.

The female of *Australomedusa* is to be described in a second paper by Russell.

The Habitat of *Australomedusa*

The South Australian lake from which *Australomedusa* was first collected was small (area ca. 5 ha), shallow, and closed (no inlet or outlet). At the time of collecting it had a salinity of 34.4‰ (Bayly 1970), which is very close to that of average sea water. However, this fact is almost certainly mere coincidence as the lake is highly astatic and variable in salinity; during the period March 1964 to December 1969 the salinity is known to have varied from 25‰ to 58‰ (Bayly 1970, fig. 2). More direct evidence that *Australomedusa* is euryhaline came in June 1970 when it was collected from a small, shallow, closed lagoon at Inverloch, Victoria. This time the salinity was only 22‰.

Occurrence of Unisexual Populations and Probable Life History

The original collection of six specimens from South Australia consisted entirely of males; the subsequent collection of more than 30 specimens from Victoria consisted entirely of females.

The occurrence of unisexual populations of medusae is well known for both *Craspedacusta* and *Limnocyda*. In these two genera the sexes are separate in both the medusoid and polypoid stages and the occurrence of unisexual medusoid populations is presumed to be the result of the introduction into a body of water of only a single polyp and its subsequent asexual propagation. The hydroid stages of these genera undergo budding to form colonial organisms which are capable of three different types of reproduction as follows:

- (1) They can bud off frustules which form new polyps.
- (2) They can form resistant internal bodies capable of withstanding unfavourable conditions
- (3) They can bud off sexual medusae

The available evidence suggests that the life cycle of *Australomedusa* is very similar to that of the Olindiidae. In view of the astatic nature of the South Australian lake, and the near certainty that its salinity fluctuations would be greater than the range of tolerance of the hydrozoan, the possession of a resistant stage would clearly be highly adaptive.

Zoogeography

Once again we are presented with the picture of a major taxon such as a class or order having an Australian representative that is quite distinct from its overseas counterparts at the generic or even familial level.

To date no limnomedusan appears to have been recorded or described from South America but on general grounds it may be expected that endemic representatives of this taxon will eventually be found in that continent. If and when this occurs, it may be a profitable exercise to examine the relationship between *Limnocyda*, *Australomedusa* and the

presently hypothetical South American taxon. It may well be that a distinctive Gondwanic grouping exists within the Limnomedusae.

References

BAYLY, I.A.E. (1970). Further studies on some saline lakes of south-east Australia. *Aust. J. mar. Freshwat. Res.* 21:117-29.

RUSSELL, F.S. (1970). On a new species of medusa from an inland salt lake in South Australia. *J. Zool.* 162:449-52

INSOLUBLE GRANULES: THEIR NATURE, ORIGIN AND ROLE IN EXCRETION IN FRESHWATER MUSSELS.

(Recorded here by title only)

by I.D. Hiscock

Department of Zoology, Monash University, Clayton, Victoria. 3168

SOME COMMENSALS OF QUEENSLAND CRAYFISH

(Recorded here by title only)

by J.R. Kane

St. Leo's College, St. Lucia, Queensland. 4067

SURVEY OF VICTORIAN NON-MARINE MOLLUSCS

(Recorded here by title only)

by B.J. Smith

*National Museum of Victoria, 285-321 Russell Street,
Melbourne, Victoria. 3000*

FISH STUDIES

THE FUTURE OF AUSTRALIAN FRESHWATER FISHES

(Abstract only)

by J.S. Lake

*School of Biological Sciences, Zoology Building,
University of Sydney, Sydney, New South Wales. 2006*

We often hear of mammals and birds which have become extinct, or are in danger of extinction, as a direct result of man's interference with these animals or their habitats. Rarely, if ever, do we hear of man's influence on fishes except when commercial exploitation reaches the point of overfishing. Contrary to popular belief this phenomenon is rare, particularly in the freshwater fisheries. Nevertheless, in Australia, a country considered by many to be underdeveloped and underpopulated, approximately *one third* (about 50

species) of our freshwater fishes, most of them endemic to Australia, are in jeopardy. A few are already seriously threatened, and we know insufficient about their biology.

Many of the adverse effects are of a "sub-lethal" nature, i.e., the fish are not killed outright, and we rarely see dead fish clogging the rivers, although even this occurrence is becoming more common due to acute poisoning by such pollutants as insecticides. However the sub-lethal effects are even more dangerous than mass mortalities, as few people are aware that these animals, most of them occurring nowhere else in the world, are unobtrusively disappearing.

The greatest sub-lethal effects come from a reduction in the fishes' capacity, or opportunity, to reproduce. This has happened in the following ways:

- (a) Siltation causing the death of eggs spawned on the stream bed.
- (b) Fluctuating water levels due to irrigation demands, which may cause the desiccation and death of eggs spawned near the surface on marginal vegetation.
- (c) Removal of snags used by some fishes, both as places to live and as spawning sites.
- (d) Dam construction which affects flooding and water temperature to an extent that some species are no longer induced to spawn.
- (e) Dam construction on coastal streams where fishes are prevented from completing their life cycles.
- (f) Insecticides washed into the water from agriculture and forestry. Insecticides are more dangerous in rice, tobacco and cotton growing areas. A preliminary study on trout in some lakes in New Zealand indicated that hatchability of the eggs was lowest where the levels of DDT and similar chemicals were highest.
- (g) Weedicides being used in irrigation and other areas such as ornamental lakes.
- (h) Increase in nitrates and other nutrients from fertilizers, sewage and other waste disposals, and motor vehicle exhausts. Nitrates at high levels of concentration cause excessive growth and then decay of algae, so that an oxygen deficiency results and fish may die. At levels of oxygen deficiency not sufficient to kill the fish outright, a sub-lethal effect can result if the fishes are not adapted for reproduction in such waters.

If we are to save our native fishes urgent action is required. We must have a good understanding of their biology and ecology, and we must prevent the changes listed above from occurring. This is only likely to happen by taking two steps, both of which are not popular in our present growth-waste economy.

These steps are: halting the population growth of man; and creating an economic system based, not on growth, but on human well-being. The alternative is not only death to our fishes and other wildlife, but eventually to man himself.

A HISTORY OF TASMANIAN FRESHWATER FISHERIES

(Abstract only)

by D.D. Lynch

*Inland Fisheries Commission, 127 Davey Street,
Hobart, Tasmania. 7000*

In 1803 Tasmania was settled by Europeans who found a depauperate fish fauna in the island's freshwaters, with the few indigenous species lacking the fighting qualities of the Northern Hemisphere's salmonids. This deficiency, together with the colonists' main objective of importing a high quality freshwater fish as the basis for a commercial fishery to supply food, motivated the first endeavours to introduce the salmonids into the Southern Hemisphere.

In the mid 19th century there was some knowledge of salmon and trout culture but early ventures to bring live ova from England to Tasmania faced insuperable difficulties caused by the slow speed of sailing ships over long distances through the tropics. Experiments carried out in London showed that the hatching of salmon ova could be delayed by keeping the ova at low temperature. Accordingly, by using large quantities of ice in a specially constructed ice house on the ship's deck, the hatching of *Salmo salar* (Atlantic salmon) and *Salmo trutta* (brown trout) was delayed whilst in transit to Tasmania by a variety of vessels. The first brown trout hatched on the 21st May, 1864, and the first Atlantic salmon the next day. The Atlantic salmon project failed but brown trout became firmly established and the species thrived in the new environment. In 1866 sea run brown trout were introduced and a further consignment was brought out in 1928. *Salmo gairdneri* (rainbow trout) were introduced in 1898 from North America, via New Zealand. A number of attempts to acclimatise *Oncorhynchus tshawytscha* (Chinook salmon) failed even though liberation of hatchery raised fish, sometimes as old as two years, continued until 1956.

A number of attempts were made to introduce *Salvelinus fontinalis* (brook trout) and only the most recent one in 1962 shows promise of establishing a self-supporting population of this species.

Evidence was presented of the status of the fisheries, the current species distribution in Tasmania, the management policy of the Inland Fisheries Commission, and the effects of large scale hydro-electric power development on the freshwater fisheries, and in particular on the "Shannon Rise."

The successful acclimatisation of salmonids resulted in recreational opportunities for over 25,000 licensed anglers each year, but the possible adverse effects on some of the unique Tasmanian fauna, especially crustaceans, mayflies and fish, has yet to be assessed.

TEMPERATURE RELATIONSHIPS IN SMALL BODIES OF FRESH WATER WITH SPECIAL REFERENCE TO TROUT STREAMS IN SOUTH AUSTRALIA

by N.M. Morrissy

*Department of Fisheries and Fauna, Western Australian Marine
Research Laboratories, North Beach, Western Australia. 6020*

The summer distribution and abundance of brown trout (*Salmo trutta* L.) and rainbow trout (*S. gairdneri* Richardson) in water-courses in the Mount Lofty Ranges near Adelaide, South Australia, were observed to fit the classical ecological model of Andrewartha and Birch (1954) during a study of these fish in the mid-sixties (Morrissy, 1967).



Fig. 1. Localities mentioned in the text. The area bounded by the Torrens and Bremer Rivers and the coastline contains the majority of trout streams in this region.

The highest observed density of fish, as numbers per unit of stream length, occurred in a tributary of the Torrens River called Sixth Creek, in the ranges just east of Adelaide (Fig. 1). In this small stream large numbers of fish were found throughout the year in both pools and shallow running water, there being no difference during summer in estimated numbers per unit volume of water over the range of water-types present. In other larger streams, pre-

dominantly those to the north and east, populations of trout were more patchily distributed along their lengths, being confined in summer to the deeper pools. In streams at the limits of the distribution, the Broughton River in the north and the Bremer River in the east, for example, repeated liberations of fish had failed to provide continuing populations, and the introduced fish survived only in very small numbers for a year or so in the deepest pools.

Multiple regression analyses of the patterns of air temperature and rainfall (indicating summer water temperatures and stream flows) over the region showed that these factors increased and decreased, respectively, with decrease in altitude and progression to the north and east from the area of lowest summer air temperatures and highest annual rainfall at the highest altitudes just east of Adelaide.

An explanation for the changes in abundance of trout over the region can be found, therefore, in the superficial pattern of weather variation. However, the status of trout in this region has been described as precarious by Weatherley and Lake (1967), no doubt because trout are commonly viewed as "coldwater" fish restricted to water temperatures below 25°C, if not 20°C. The region has a hot, dry, Mediterranean-type summer, when maximum air temperatures regularly exceed 35°C (95°F). However, self-sustaining stream populations of trout (mainly brown trout), providing excellent angling, have existed for at least 50 years, and possibly 90 years, their establishment being initially achieved from very small liberations (less than 2000 fry in many cases).

In view of the above paradox some attention was given to the following questions:

- (a) Were the trout in South Australia better genetically adapted to resist death at high water temperatures than members of the same species in colder regions of the world?
- (b) Were the water temperatures experienced by the fish really as high as the climate of the region suggested and how important for survival were the low stream flows during summer?

Lethal temperature experiments revealed that brown trout fry of wild parents from the Torrens - Sixth Creek system were not significantly more resistant than brown trout fry reared from eyed ova brought from Snob's Creek, Victoria, although rainbow trout fry from the latter source were less resistant. Brown trout fry were more resistant than brown trout in their second year of life. Brown trout fry tested in one year were more resistant than fry tested in another year when the temperatures of acclimatization were lower. The temperature values associated with deaths in these experiments were in general agreement with those of Affleck (1952). Statistical comparison of the resistance times of the Australian trout with those of Canadian trout (Fry, 1947; Pearson, 1951; Craigie, 1963) are not possible because the latter fish were tested over a lower range of lethal high temperatures. However, Fig. 2 clearly shows that the Australian fish were certainly not extraordinarily more resistant to lethal temperatures than the Canadian ones.

For Sixth Creek the average monthly water temperatures for each of 24 hourly points in the daily temperature cycle were computed from daily thermistor records taken over two years of typical cold, wet winters and hot, dry summers. A summary of the turning points of the average monthly diurnal cycles (Table 1) shows that there was insufficient time during the prevailing high daytime air temperatures of summer for the water to heat up to lethal levels for the trout from the minimum levels of early morning. The daily survival of the trout appeared to depend very much upon the longer period of cooling of the water overnight. The length of time in which direct insolation of the water of the stream occurred during a single diurnal cycle was restricted by the aspect and nature of the creek valley.

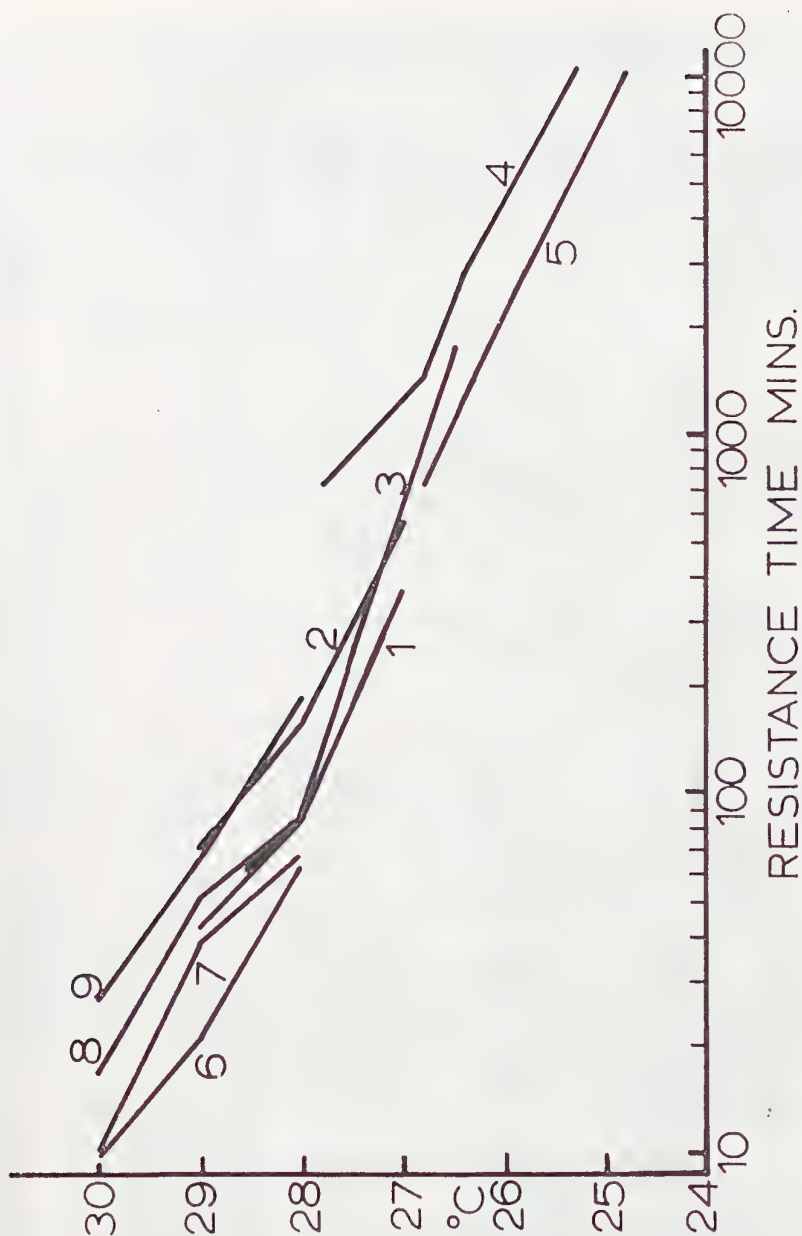


Fig. 2. Lethal temperatures of trout.

1. Canadian rainbow trout yearlings; accl. temp. 20°C; Craigie (1963).
2. As for 1.
3. Canadian brown trout yearlings; accl. temp. 20°C; Fry (1947).
4. Canadian brown trout, age unknown; accl. temp. 23°C; Pearson (1951).
5. As for 4 except accl. temp. 20°C.
6. South Australian brown trout, age 1+; accl. temp. 17.8 – 21.8°C (1964).
7. Victorian rainbow trout, age 0+; accl. temp. as for 6.
8. South Australian brown trout, age 0+; accl. temp. as for 6.
9. South Australian brown trout, age 0+; accl. temp. 19.5 – 23.0°C (1963).

TABLE 1
AVERAGE MONTHLY WATER TEMPERATURES (°C) FOR SIXTH CREEK SOUTH AUSTRALIA FROM
CONTINUOUS RECORDS (JUNE 1963 TO MAY 1965)

1963-64												
MAXIMUM (S.E. OF MEAN)	11.5 (0.7)	11.2 (0.9)	12.1 (0.8)	14.7 (1.9)	18.9 (1.8)	20.1 (2.2)	21.8 (1.2)	21.7 (1.4)	21.1 (1.8)	19.0 (1.0)	16.3 (1.6)	12.9 (1.4)
TIME OF DAY P.M.	3	5	4	4	5	4	4	5	5	5	5	5
MINIMUM (S.E.)	10.1 (1.0)	9.8 (1.2)	10.2 (1.0)	11.5 (1.0)	14.2 (1.2)	16.1 (1.7)	16.1 (2.6)	17.2 (1.4)	17.0 (1.8)	15.1 (1.0)	13.6 (1.4)	10.2 (1.8)
TIME OF DAY A.M.	10	8	10	8	7	8	9	9	9	9	9	10
MAXIMUM (S.E.)	10.9 (1.7)	10.8 (0.6)	11.6 (0.8)	13.5 (1.4)	15.5 (2.1)	19.4 (2.7)	19.5 (1.5)	21.1 (1.2)	21.9 (0.8)	20.7 (1.4)	15.8 (1.4)	13.3 (1.3)
TIME OF DAY P.M.	5	5	5	2	2	2	2	6	6	3	3	1
MINIMUM (S.E.)	9.1 (2.0)	9.2 (0.9)	9.4 (1.1)	10.8 (1.3)	12.2 (0.9)	15.0 (1.7)	15.8 (1.3)	17.7 (0.7)	18.3 (1.0)	15.9 (1.8)	13.1 (1.3)	11.7 (1.2)
TIME OF DAY A.M.	9	9	9	8	8	8	8	10	9	10	9	10

The major rivers flowing east to west through the Mount Lofty Ranges are antecedent streams, there being a precipitous western escarpment just east of which they flow tortuously through deep, steep-sided gorges. The confluence of the Torrens River and Sixth Creek occurs in such a gorge.

The daily minimum air temperatures at the creek level (altitude 183 m) were always lower than the corresponding values at Adelaide on the plains (altitude 43 m) and the differences between these minima showed a strong acceleratory correlation with the corresponding daily maxima (Fig. 3; c.f. the differences between the maxima at Sixth Creek and Adelaide). The diurnal range of air temperatures is maximal during summer and this range is strongly accentuated in the valleys of streams on the hottest days because early morning temperatures are lower than in places of level terrain.

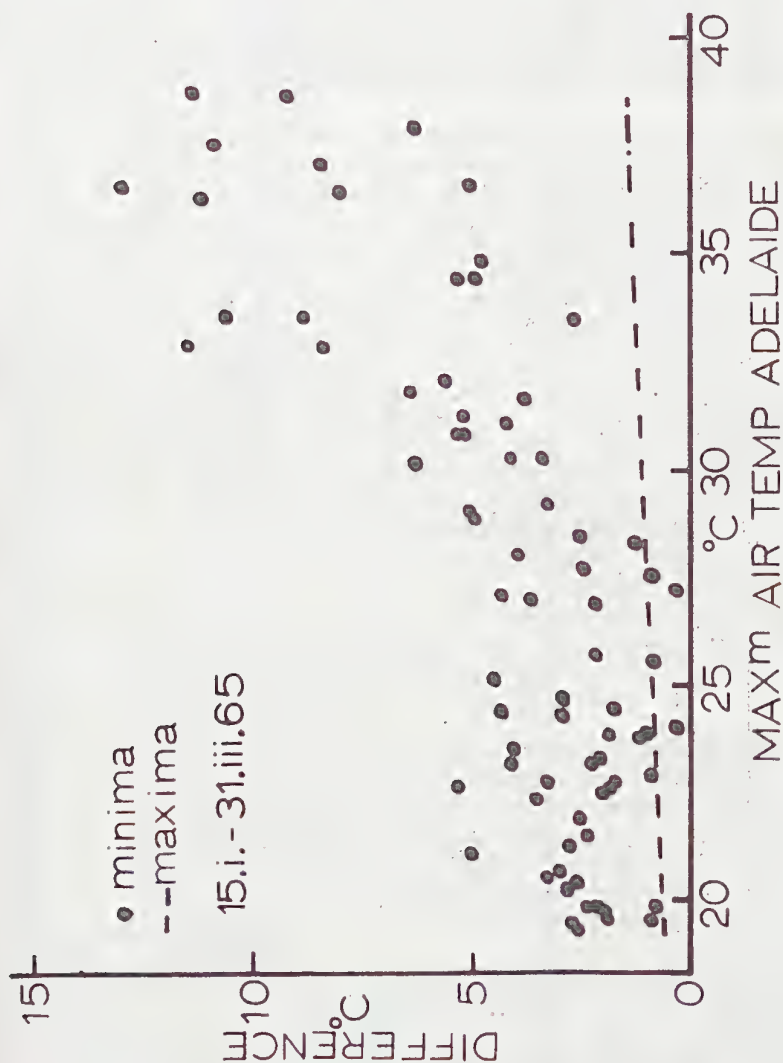


Fig. 3. Difference between air temperatures at Adelaide and Sixth Creek during summer.

TABLE 2
MULTIPLE REGRESSION ANALYSIS OF THE RELATIONSHIP BETWEEN DAILY WATER AND AIR TEMPERATURES
(°C) AT SIXTH CREEK (JUNE 1964 – MARCH 1965)

	Constant term	Coefficient for x_1	Coefficient for x_2	"t" for Coeff. $x_2 = 0$	Degrees of freedom	R^2 (%)
	Maximum water temp. (y) on maximum air temp. (x_1) and the difference (x_2) between y and the preceding minimum water temperature.					
"Winter"	2.0335	0.2983	-0.4863	0.43 n.s.	78	25.5
"Spring"	1.0779	0.3532	0.4557	3.94 sig.	85	66.7
"Summer"	10.0452	0.2082	0.3990	5.27 sig.	117	56.2
	Minimum water temp. (y) on minimum air temp. (x_1) and the difference (x_2) between y and the preceding maximum water temperature.					
"Winter"	3.5558	0.2577	-0.2893	0.43 sig.	78	57.5
"Spring"	-0.5278	0.4698	0.1874	1.92 n.s.	85	47.6
"Summer"	1.7446	0.4947	-0.0023	0.24 n.s.	117	54.7

All the coefficients for x_1 are significant with $P(|t_{60} \rightarrow 1.20| > 2.00 \rightarrow 1.99) = 0.05$

Multiple regression analyses showed that daily maximum water temperature during the "spring" and "summer" months was positively correlated with the preceding minimum water temperature on the same day as well as with the maximum air temperature (Table 2). However, the day to day variations in minimum water temperature during the hotter months were not statistically dependent upon the preceding maximum water temperature; the daily period of cooling of the water was apparently sufficiently long for a relative degree of independence to occur. (The minimum water temperature during "winter" was negatively correlated with the maximum water temperature on the preceding day since warm winter days with clear skies are usually followed by very cold nights, due to frosts).

The study section of Sixth Creek (1,340 m upstream from the Torrens River confluence) was relatively unshaded by trees. In summer a massive bloom of filamentous green algae (*Cladophora* spp.) formed in all the water-types. Where the algae formed a floating mat on the pools, daytime temperatures reached 29-30°C in the water on the surface of the mat but only 21.4 – 24.3°C just beneath it (ca 8 cm down). The algae also formed mats (as much as 30 cm thick) on the bottoms of the deeper pools, and this layer contained cooler water (up to 2.3°C cooler than the water immediately above it) into which trout were often observed to move during the daytime.

Oxygen concentrations of Sixth Creek water samples were either at saturation or supersaturation during summer from early morning to late afternoon.

Temperature stratification was found during the mid-afternoon of summer days in the 5 deep pools in the study section of Sixth Creek. These pools, of average length 28 m and average width 3.5 m, had maximum summer depths of 0.9 to 1.1 m. The large numbers of trout present (up to 30 per pool) tended to disrupt temperature stratification. Not including the cold water contained by bottom algae, the maximum difference found between surface and bottom water was 4.1°C (maximum depth 1.1 m) under clear-water conditions.

Measurements of water temperature with depth in deeper pools containing trout in other rivers also indicated that temperature stratification was the phenomenon which permitted the survival of trout in water less favourably situated with respect to factors of climate and topography than Sixth Creek (Table 3). Not only did the patchy distribution of trout along these streams obviously correlate with the incidence of deeper water but there was also an observed lack of surface feeding activity, or any visual sign of fish, during the intense daytime heat of summer. In addition, vigorous, highly conditioned fish, often containing newly ingested food, could be captured only by the use of weighted lures fished very close to the bottoms of the pools.

It is suggested that temperature stratification in stream pools accounts for a considerable extension of the distribution of trout, at least from cooler summer-regions into hotter ones, in small bodies of water. Examples include Mosquito Creek at the S.A. – Victorian border near Naracoorte (personal observation) and the Group I streams described by Lake (1957) in a major survey of trout habitats in N.S.W.

For temperature stratification to occur during summer the flow of water through pools must be very small or absent. The very large seasonal changes in flows of S.A. streams are similar to those of Sixth Creek (Fig. 4). The natural summer flow in most streams is very small, less (usually much less) than 100,000 litres/hour and in the rest of the streams zero for all, or part of, the summer. The stream flow is usually introduced onto the surface of pools from a small, shallow channel. Survival of trout occurs where these small surface flows (and subsurface flows and springs) suffice to maintain sufficient depth of water in pools to insulate the fish from the daytime heat.

The pools commonly occur at bends or in places of steep gradient. They usually have steep banks and show very little change in area at different flow rates (c.f. "shrunk" drought-stricken streams in colder climates).

Occasionally isolated downpours of warm cyclonic rain occur in the Mount Lofty Ranges during summer. Since 1884 records showed that summer floods may occur once in every five years for a particular river system. In Sixth Creek, during December 1965, lethal water

temperatures occurred during flooding of heavy rain off the warm ground of the watershed, and also later when the flow of the creek ceased and the surviving fish were crowded in the few remaining deep, muddy pools.

TABLE 3
MEASUREMENTS OF THE CHANGE IN TEMPERATURE WITH DEPTH
IN SOME STREAMS AND A DAM IN SOUTH AUSTRALIA
(TIME OF DAY 3.00 – 5.45 P.M.)

Date	Locality	Depth (Metres)	Max. Air Temp. in Sun (°C)	Surface Temp. (°C)	Bottom Temp. (°C)	Temp. Difference (°C)	Area (Sq. Metres)
13.11.65	Light R.	1.4	29.4	25.7	21.4	4.3	37.2
"	"	0.5	" (28.3)*	26.9	26.9	0.0	9.8
"	"	2.0	"	26.1	19.9	6.2	306.6
"	"	1.5	"	26.1	20.2	5.9	"
21.11.65	Delamere Dam	2.8	28.9 (38.9)*	22.3	18.1	4.2	12727
27.11.65	Light R.	2.0	28.3	27.1	20.4	6.7	304.2
"	"	1.7	" (27.8)*	26.7	21.1	5.6	"
"	"	2.1	"	26.7	20.75	5.95	585.3
"	"	1.4	"	26.7	22.1	4.6	"
"	"	1.1	"	26.3	23.0	3.3	224.3
"	"	1.3	"	26.1	21.9	4.2	696.8
"	"	1.8	"	25.7	21.0	4.7	141.6
28.11.65	Bremer R.	1.3	37.2	26.9	22.1	4.8	87.6
"	"	1.8	" (31.7)*	26.3	21.25	5.05	730.2
"	"	1.1	"	28.45	21.4	7.05	288.0
"	"	2.9	"	26.5	21.1	5.4	731.2
14.1.66	Broughton River	5.2	45.6	26.35	20.45	5.9	1214.2
"	"	2.6	" (40.6)*	28.3	26.25	2.05	2329.9
"	"	4.9	"	28.1	21.3	6.8	2325.3
"	"	1.1	"	30.45	26.3	4.15	59.9
"	"	2.1	"	30.9	24.5	6.4	418.1
"	"	1.1	"	27.7	27.65	0.05	6069.2
21.1.66	Light R.	1.3	37.8 (31.7)*	26.3	20.7	5.6	2229.6
"	"	2.3	"	26.5	18.95	7.55	"
"	"	1.3	"	26.3	21.2	5.1	"
"	"	1.5	"	27.75	18.7	9.05†	372.5
"	"	1.5	"	27.3	18.8	8.5 †	"
"	"	2.9	"	26.0	18.85	7.15	819.4
"	"	3.0	"	26.0	18.9	7.1	"
"	"	2.1	"	25.7	19.3	6.4	"
22.1.66	Delamere Dam	4.4	25.0	24.35	16.25	8.10	12727.3
"	"	5.0	" (30.6)*	24.35	15.2	9.15	"
"	"	1.4	"	27.1	26.65	0.45	2633.7
25.1.66	Sixth Ck.	1.0	35.0 (36.7)*	24.7	18.5	6.2 †	81.8
"	"	0.8	"	27.05	20.25	6.8 †	149.6

* Maximum air temperature at Adelaide
† Turbid

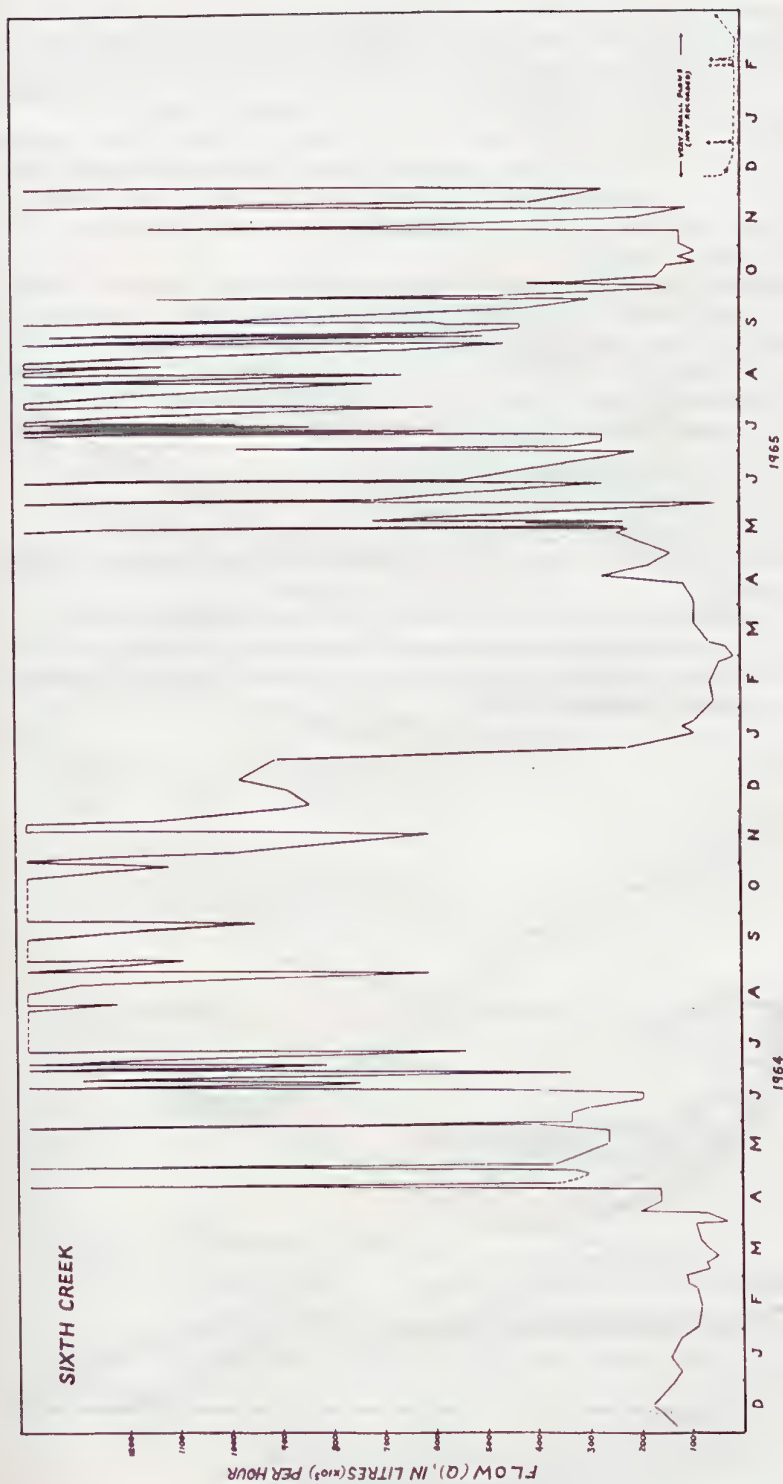


Fig. 4. Rate of flow of Sixth Creek.

Except for the above unseasonal events, the trout in S.A. did not appear to experience very high water temperatures continually during summer. Not only was there the period of overnight cooling of the water each day after the shorter period of daytime heating but also "cool spells" of several days alternating with hotter periods. In addition, during the daytime the water in deeper pools is not uniformly heated. Through behavioural adaptations the trout probably make full use of these natural variations in time and space not only to survive from day to day but also to feed efficiently and hence grow and undergo gonadal maturation during summer. The ranges of temperatures within which the latter processes can proceed, so that the population may continue to survive, are narrower than those for short term individual survival (Brett, 1962).

The thermal stratification of lakes during summer is well-known. By comparison "microthermoclines" of small bodies of water seem to have received scant attention even since the review by Young and Zimmerman (1956). Into the latter category may be placed the deeper pools (greater than about 1 m in depth) of streams which have a very restricted flow during summer. Very little attention has also been given to the permanency of such "microthermoclines" and the bearing of their stability on the survival and productivity of the biota (Vaas and Sachlan, 1955).

For the data in Table 3 the linear regression of bottom water temperature on depth accounted for 51.3% of the variability in temperature which decreased on the average by 1.77°C per metre increase in depth over the range 1-5 m, excluding the data from the Broughton River which showed a similar slope but a significant (higher) displacement from the body of the data.

The difference between surface and bottom water temperatures was significantly correlated with depth and maximum air temperature. The influence of other variables such as wind, area, shape, and turbidity may perhaps best be ascertained by using model systems of the type described by Vallentyne (1967).

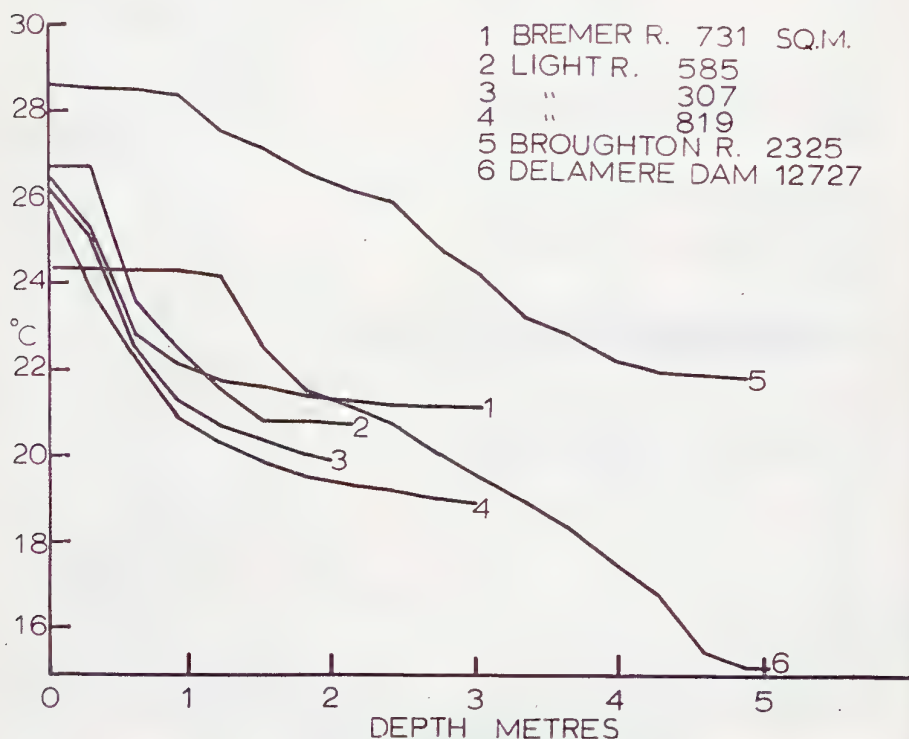


Fig. 5. Change in temperature with depth in pools.

The shape of the curves of temperature on depth for the smaller pools appeared to reflect the classical relationship of light absorption by still water, there being only a few centimetres of homothermy at the surface, due to wind, in a few cases (Fig. 5). Over 50% of solar radiation is absorbed within 2 m of the surface of freshwater and 99% of infrared (820mu) within 2 m (Reid, 1961).

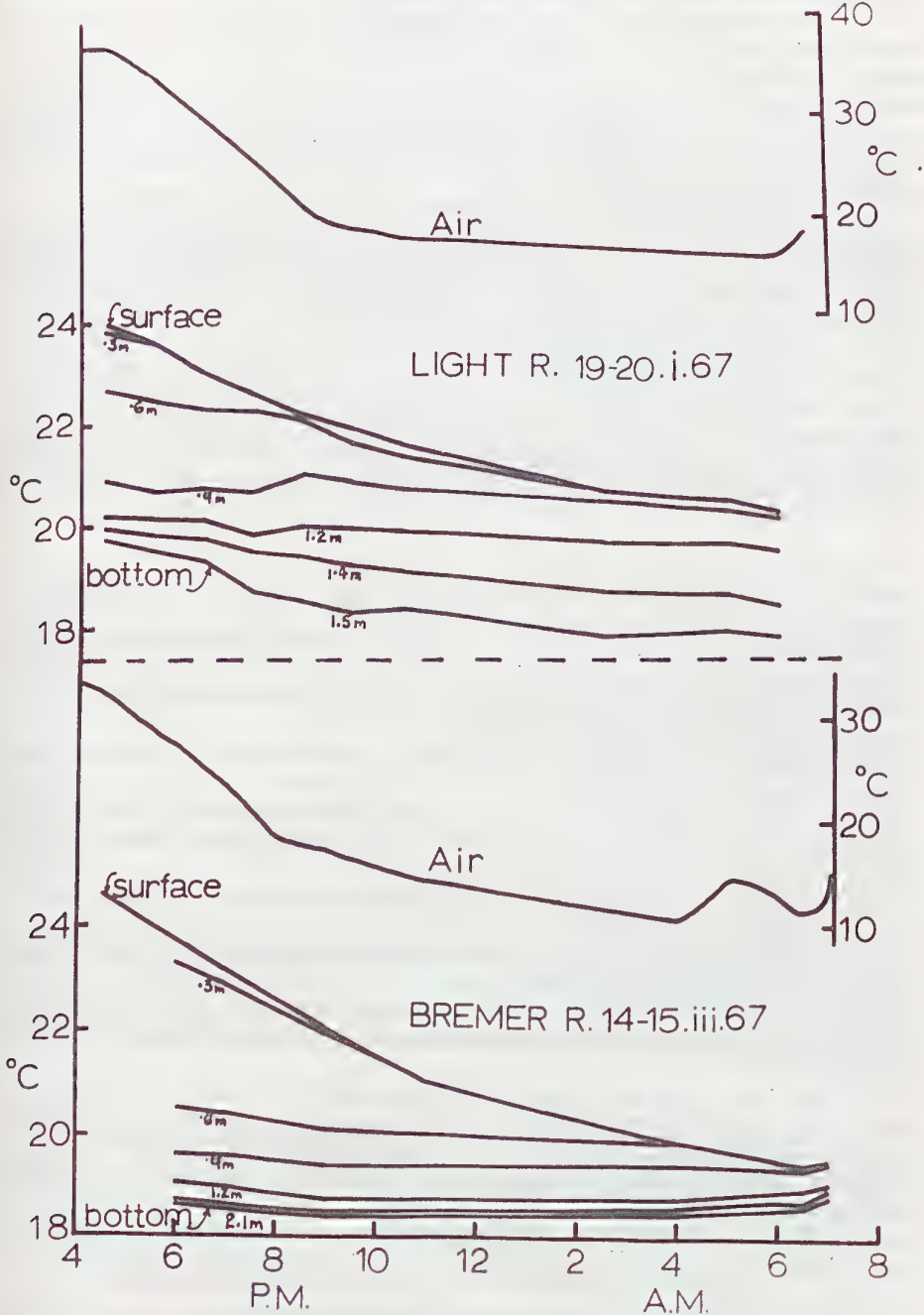


Fig. 6. Overnight changes in temperature stratification in pools.
Light R. slight flow, sky overcast. Bremer R. no flow, sky clear.

Surface activity of trout in these pools during the late evening or early morning (and their capture during daytime only close to the bottoms of pools) suggested that stratification was ephemeral, and that circulation, with oxygen replenishment, occurred. Opportunities for further investigation in S.A. were limited to two occasions which, however, supported the occurrence of opportunities for frequent but not daily turnover (Fig. 6).

It is suggested that the distribution of trout cannot be extended into hotter regions by providing even deeper pools. The temperature of the water near the bottoms of the pools might be low enough for trout but there would be insufficient oxygen for their survival. A depth is reached where circulation of water near the bottom would not occur, or too infrequently, because surface cooling does not reach the bottom water overnight. A natural pool of such depth, and showing continuous temperature stratification during summer, would approach the dimensions of a lake.

Transient temperature stratification has recently been found to be an extremely important factor in determining the summer survival, and a favourable temperature range for growth, of a bottom living decapod, *Cherax tenuimanus* Smith, in turbid, clay-bottomed farm dams in the hotter regions of south-western W.A. Studies of such habitats have been carried out over the past eighteen months. In dams (about 30 m x 30 m, by 3-4 m deep, with turbidities of 10-50 cm by Secchi disc) temperature differentials up to 14°C have been measured (a 10°C decrease in the first metre of depth). The decapods failed to survive a summer in one dam (more turbid and with cooler bottom water) where minimum surface temperatures failed to equalize with minimum bottom temperatures at least once a month. Mortality was due to a measured oxygen deficiency above the thick bottom layer of organic ooze and detritus. More intensive investigations of these relationships are now being pursued.

References

- AFFLECK, R.J. (1952). Zinc poisoning in a trout hatchery. *Aust. J. mar. Freshwat. Res.* 3: 142-69.
- ANDREWARTHA, H.G. and BIRCH, L.C. (1954). *The distribution and abundance of animals*. Univ. Chicago Press, Chicago.
- BRETT, J.R. (1962). Thermal requirements of fish - three decades of study, 1940 - 1970. *Stud. Fish. Res. Bd Can.* 1960: 587-634.
- CRAIGIE, D.E. (1963). An effect of water hardness in the thermal resistance of the rainbow trout (*Salmo gairdneri* Richardson). *Can. J. Zool.* 41: 825-830.
- FRY, F.E.J. (1947). Temperature relations of Salmonoids. Proceedings, 10th Meeting of the Executive of the National Committee on Fish Culture. Fisheries Research Board of Canada and National Research Council, Ottawa. Appendix "D": 1-5.
- LAKE, J.S. (1957). Trout populations and habitats in New South Wales. *Aust. J. mar. Freshwat. Res.* 8: 414-450.
- MORRISSY, N.M. (1967). The ecology of trout in South Australia. Ph.D. thesis. University of Adelaide, Adelaide, South Australia.
- PEARSON, B.E. (1951). Provisional upper lethal temperatures for *Salmo fario*. Annual Report No. 23. Laboratory for Experimental Limnology, Southern Research Station, Maple, Ontario.
- REID, G.K. (1961). *Ecology of inland waters and estuaries*. Reinhold, New York.
- VAAS, K.F. and SACHLAN, M. (1955). Limnological studies on diurnal fluctuations in shallow ponds in Indonesia. *Verh. int. Verein. theor. angew. Limnol.* 12: 309-319.
- VALLENTYNE, J.R. (1967). A simplified model of a lake for instructional use. *J. Fish. Res. Bd Can.* 24: 2473-2479.
- WEATHERLEY, A.H. and LAKE, J.S. (1967). Introduced fish species in Australian inland waters. *Australian Inland Waters and their Fauna* A.H. Weatherley, Ed., A.N.U. Press, Canberra.
- YOUNG, F.N. and ZIMMERMAN, J.R. (1956). Variations in temperature in small aquatic situations. *Ecology* 37: 609-611.

SOME ASPECTS OF INTER-SPECIFIC COMPETITION BETWEEN BROWN AND RAINBOW TROUT IN LAKE EUCUMBENE, NEW SOUTH WALES

(Abstract only)

by R.D.J. Tilzey

*New South Wales State Fisheries, 211 Kent Street,
Sydney, New South Wales. 2000*

Initial analysis of catch and tagging data for the 1968/69 angling season showed Eucumbene to hold approximately 1.7×10^5 brown trout and 0.8×10^5 rainbow trout, aged one year and above. More recent data indicate the brown: rainbow ratio to be increasing.

Tagging studies over three years showed that 23 to 30% of catchable rainbow trout (of lengths greater than 25 cm) were caught by anglers during the 12 months following tagging, whereas the corresponding figures for brown trout were only 6 to 12%. Food studies showed both species to have similar diets and inter-specific competition to undoubtedly occur. Inter-specific predation under lentic conditions favours brown trout, the percentage occurrence of (I+ and above) rainbow trout in brown trout stomachs being 0.82% as against nil for the opposite. The number of brown trout present at any one time is also favoured by their comparative longevity (0-VII years) as against that of rainbow trout (0-V years).

Although the above show that exploitation, predation and age expectance favour brown trout, and that inter-specific competition for food occurs, these facts do not contribute greatly to the marked brown: rainbow imbalance. Annual natural mortality after age I is similar for both species under lentic conditions, initial analysis of data indicating it to be between 40 and 50%.

It is suggested that differential mortality in the first year of life for each species, as a result of direct inter-specific competition is the major cause of this imbalance. A representative study area was chosen and the spawning and subsequent development of both species closely monitored. Mortality through ova-predation and redd-superimposition is high for both species, with the later-running rainbow trout being favoured on the latter count.

The majority of brown trout spawned before rainbow trout and likewise a major proportion of their ova were found to hatch at least one month prior to those of the rainbow trout. Consequently the later-developing rainbow trout fry found suitable feeding stations already occupied by brown trout and were forced to migrate downstream to the Lake. The lotic-lentic interface is characterised by the presence of numerous large (30-74 cm) brown trout, and rainbow trout fry-fingerling mortality is high (23.7% frequency of occurrence in stomachs).

The majority of brown trout enter the Lake as yearlings and as such are less liable to lentic predation. That the early downstream migration of rainbow trout fingerlings was not simply an innate behavioural response was indicated by simultaneous sampling of one of the few creeks used solely by spawning rainbow trout. Rainbow trout fingerlings were present in significant densities (2.9 per M^2 of substrate) as against nil in the shared spawning stream (brown trout fingerlings 3.9 M^2). Further experiments are in progress to clarify this matter.

ARTIFICIAL PROPAGATION OF THE MACQUARIE PERCH

(Recorded here by title only; publication to follow in
a future issue)

by J.C.F. Wharton

*Fisheries and Wildlife Department, 605 Flinders Street Extension,
Melbourne, Victoria. 3000*

POLLUTION SYMPOSIUM

(Held in association with the Australian Conservation Foundation
and the Tasmanian Conservation Trust)

BASIC CAUSES OF POLLUTION

(Recorded here by title only)

by J.S. Lake

*School of Biological Sciences, Zoology Building,
University of Sydney, Sydney, New South Wales. 2006*

LESSONS IN POLLUTION CONTROL PLANNING

(Recorded here by title only)

by R.D. Piesse

*Australian Conservation Foundation, 191 Royal Parade,
Parkville, Victoria. 3052.*

POLLUTION OF THE SOUTH ESK RIVER, TASMANIA, BY MINE EFFLUENTS

(Abstract only)

by P.A. Tyler and R.T. Buckney

*Department of Botany, University of Tasmania,
Box 252C, G.P.O., Hobart, Tasmania. 7001*

Extraction of tin and wolfram from mines in north-eastern Tasmania has produced the familiar pattern of polluted rivers and degraded agricultural land. While palliative measures such as new settling ponds and liming have had partial success, they do little to reduce soluble pollutants and their effectiveness is reduced by discharge of mineral particles by accident, negligence or dereliction.

The principal pollutants (zinc, copper, cadmium and sulphuric acid) destroy or deter trout in the South Esk River. Aberfoyle and Storys Creeks are biologically dead. Rich dairy pastures have been laid waste by toxic sediments, and irrigation denied by soluble pollutants.

The long-term effects of sublethal pollution bear close scrutiny. Poisoned lands may be recolonized by pasture plants genetically tolerant to metal toxins in their internal environment. Irrigation with water meeting present international standards may lead to gradual attainment of toxic levels. In both cases biological concentration through man's food chain is a possibility.

ORIGINAL CONTRIBUTIONS NOT READ AT TENTH ANNUAL CONGRESS OF A.S.L.

IONIC REGULATION IN AQUATIC ANIMALS AND THE MODE OF ACTION OF CERTAIN PESTICIDES

by J.W. Steen*

*Department of Zoology, Monash University, Clayton
Victoria. 3168*

(Manuscript received January 1971)

* Mr. Steen died suddenly in January 1971 after completing one year of study for the degree of Ph.D. under the supervision of Dr. W.D. Williams. Shortly before his death he had prepared a summary of his thoughts and plans on the topic of his doctoral research. This summary is of considerable interest and it is therefore published here with only minor amendments. The title, however, has been altered so that it is more descriptive of the contents.

Two approaches are envisaged. Initial plans and thoughts tended toward a strictly ecological approach in assessing the effects of persistent chemical pollutants on aquatic ecosystems; for example, adding small amounts of radioactively labelled chlorinated pesticides to ponds, lakes and/or microcosms and then monitoring pesticide residues and typical limnological parameters. The precedent for this line of approach was established as early as the 1950's and these types of data are regularly collected by governmental authorities (particularly in the United States). However, results, apart from cases of severe contamination of aquatic environments, have been of limited use in understanding longterm and sublethal effects of these pollutants. Persistent synthetic chemicals can have a range of effects on individual aquatic species, from initial direct toxic effects to food chain concentration effects and sublethal dosage effects. Even using "simple" microcosms, a strictly empirical approach would be unlikely to give any great insight into the effects of this unique and important group of toxicants, persistent synthetic compounds.

It would seem that only after first looking at the effects of these toxicants on the individual aquatic organisms of a particular ecosystem can we hope to interpret ecosystem "responses" to these contaminants. Toxicity experiments are reasonably standard and for chlorinated hydrocarbon LC₅₀ determinations, the toxicant is usually dissolved in acetone (or a similar low molecular weight, water-miscible solvent) prior to addition to water; this is designed to give good dispersal of the very water-insoluble chlorinated hydrocarbons. However, in real aquatic environments, the "solvent" is typically a high molecular weight lipid or an organic material (detritus). The nature of the "solvent" may influence the rate of penetration and uptake of the chlorinated hydrocarbon by the live organism (and consequently determine toxicity) via the gut or "integument". It is possible, therefore, that there is a disparity between laboratory-determined toxicity data and toxicity of these compounds in the field. To test this idea the effect of various solvents on LC₅₀ values will be determined. One very useful "solvent" appears to be polyvinyl pyrrolidone which is not transported across cell membranes and forms a true colloidal solution in water. In fact, this compound appears to be an ideal substitute for acetone in standard LC₅₀ determination.

The mode of action of D.D.T. on susceptible organisms (usually arthropods) is still a contentious issue 25 years after the first detailed studies. A recent paper (Holan 1969) outlined an empirical model for the mode of action of D.D.T. based on its stereochemical

properties. From this model Holan predicted and synthesised a number of compounds with insecticidal activity similar to, or better than, D.D.T. Also of interest in this connection are a series of papers by Weiss relating to energy transducing reactions in biological membranes (e.g. Weiss 1969). Weiss's model incorporates an explanation of selective ion permeability and active transport. He proposes that a phospholipid component of nerve and other membranes acts as an ion-exchange polymer. Depending on whether the helical phospholipid is in an expanded or contracted state, the membrane is Na^+ or K^+ permeable. Anaesthetics, it is suggested, "freeze" the contracted K^+ state, and D.D.T., the expanded Na^+ state, resulting in Na^+ "leakage". Weiss suggests that this phospholipid ion-exchange model for nerve membrane Na^+/K^+ selectivity is equally applicable to other membranes where active transport of ions takes place, and further suggests that selective transport of Cl^- across membranes is due to the same mechanism.

The papers by both Weiss and Holan suggest to me that *the primary target of D.D.T. in certain aquatic gill breathers may be the ionic regulatory mechanism located in the gills, the central nervous system being a secondary target*. If true, this postulate would neatly explain some ambiguous and confusing facts found in the literature.

Thus, why, of all the vertebrates, are fish three to four times more susceptible to D.D.T. than other vertebrates? Why do fish appear "to die of suffocation, rather than due to direct affects on the central nervous system" (Rudd 1964)? And why is *Artemia salina*, probably the best osmo- and ionic regulator, the most susceptible species to D.D.T.?

To test the hypothesis that D.D.T. (and its analogues) interferes with active transport of ions in euryhaline species, *Artemia salina* is being cultured for experimental work.

A. salina was selected because its osmoregulatory and ion regulatory mechanisms have been well studied and documented. *Artemia* maintains a fairly constant haemolymph osmolarity irrespective of the osmolarity of the external medium; it swallows external medium, actively takes up Cl^- , Na^+ and water via the gut, and then actively excretes excess Cl^- via the gills. However, the major site of regulation (and therefore the postulated primary target for D.D.T.) is the gills.

To demonstrate that ionic regulation is impeded by D.D.T., a series of experiments is planned.

1. On the basis of the above hypothesis, the greater the ionic gradient between the haemolymph and the external medium (demanding the greatest active transport activity), the more susceptible this mechanism is to D.D.T. Thus a series of LC_{50} trials under conditions of different D.D.T. concentrations and different salinities should show that D.D.T. toxicity to *Artemia* increases with increasing osmotic stress. (A computerised probit analysis programme for statistically analysing LC_{50} and LC_{90} values and their confidence limits has been prepared.)
2. For confirmation of the above, the haemolymph osmolarity (by freezing point depression measurement) under conditions of different salinity and D.D.T. concentration will be determined.
3. Measurement of both electrical potential difference in *Artemia* and ion concentrations in the haemolymph should indicate whether active Cl^- transport or facilitated Na^+ diffusion is inhibited by D.D.T..

One obvious alternative explanation to the Weiss/Holan model for the mode of D.D.T. action, should results indicate that the active transport mechanism is inhibited, is that D.D.T. inhibits enzyme activity in the biochemical reactions associated with active transport such as alkaline phosphatases and A-T-P-ases. Thus it may be necessary to extract and test

gill A-T-P-ase and alkaline phosphatase activity in the presence and absence of D.D.T.

After obtaining sufficient evidence to substantiate that D.D.T. interferes with ionic regulation in *Artemia*, it is proposed to survey a range of euryhaline species to gauge the universality of D.D.T. interference with ionic regulation — e.g. salt lake ostracods, copepods, *Parartemia*, estuarine crabs, teleost fish.

While studying the effects of D.D.T. on ion pumps, analogues of D.D.T., such as D.D.E. and D.D.D., will also be tested. It is suspected that the same mechanism of ionic inhibition might be involved but to a lesser degree because of their lesser stereospecificity compared with D.D.T.

One of the most controversial studies on the ecological consequences of D.D.T. pollution has been that on photosynthetic inhibition by D.D.T. in phytoplankton. Recent work has shown that only certain species of phytoplankton are affected but these studies inferred a change in species dominance of phytoplankton populations due to the effect of D.D.T. However, no detailed explanation has been offered for photosynthetic inhibition in phytoplankton thus far.

The Hill reaction in photosynthesis — photolysis of water which provides H radicals for reductive processes and electrons for replenishment of the chlorophyll — is the target of many herbicides. D.D.T. is known to reduce Hill reaction activity in barley chloroplasts and it may be that D.D.T. inhibits the Hill reaction in D.D.T.-susceptible phytoplankton. Hill reaction activity is measured by a fairly simple biochemical technique. It is proposed that cultures of saline-lake phytoplankton be established and the effects of D.D.T. on ^{14}C -assimilation be determined. D.D.T.-susceptible cultures could then be tested for Hill reaction activity in the presence and absence of D.D.T.

Having tested these models of D.D.T.-toxicity in the laboratory, the next step is to show their significance in the field; this will form the second part of the project.

References

- HOLAN, G. (1969). New halocyclopropane insecticides and the mode of action of D.D.T. *Nature, Lond.* 221: 1025–9.
RUDD, R.L. (1964). *Pesticides and the Living Landscape*. Faber and Faber; London.
WEISS, D.E. (1969). Energy-transducing reactions in biological membranes. II. A molecular mechanism for the permeability changes in nerve during the passage of an action potential. *Aust. J. biol. Sci.* 22: 1355–71.

FAUNISTIC AND ENVIRONMENTAL STUDIES ON LAKE MODEWARRE, A SLIGHTLY SALINE ATHALASSIC LAKE IN SOUTH-WESTERN VICTORIA

by D.A. Pollard*

*Department of Zoology and Comparative Physiology, Monash
University, Clayton, Victoria. 3168*

(Manuscript received January 1970)

* *Present address:*

New South Wales State Fisheries, 211 Kent Street, Sydney, N.S.W. 2000

SUMMARY

Physiographic, climatic, chemical, and especially faunistic data, collected over a three year period for Lake Modewarre, a slightly saline athalassic lake in south-western Victoria, are presented and discussed with particular reference to a recent chemical and faunistic study of a number of other more highly saline lakes in the same general region. Emphasis is placed on

the common volcanic origin, chemical similarities, and in particular the faunistic affinities of Lake Modewarre and the nearby "Corangamite series" of lakes included in the above-mentioned study. A gradual fall-off in concurrence of faunal elements (most of which are of fresh-water affinities) with increasing salinity in Lake Modewarre and the various lakes of the "Corangamite series" is noted, and it is concluded that any clear division of the lakes in this area into "fresh" or "saline" environments based upon faunistic criteria would be artificial.

INTRODUCTION

During the course of a study of the biology of a landlocked form of the salmoniform fish *Galaxias maculatus* (= *attenuatus*) (Jenyns) a considerable amount of information was accumulated on the physiography and origin, climatic conditions, chemistry, flora, and especially the fauna, of the saline lake in which this fish occurs. Much of this information on Lake Modewarre is of particular interest in relation to the work of Bayly and Williams (1966), who studied the chemical and faunistic features of three groups of saline lakes further to the west in Victoria and south-eastern South Australia.

Bayly and Williams concentrated their work on athalassic lakes of relatively high salinity, because although much faunistic information had been accumulated in relation to freshwater lakes throughout the world very little comparative data were available on saline lakes of non-marine origin. Although stressing that the boundary between "fresh" and "saline" waters is arbitrary, these authors adopted the convention that saline waters are those having a salinity of greater than 3‰. Their studies, however, were mainly on lakes in the higher salinity ranges (most of them having maximum observed salinities of between 30 and 300‰.) The lowest maximum observed salinity of any of the lakes which they studied was approximately 18‰. The present study of Lake Modewarre (maximum observed salinity approximately 5‰) thus helps to bridge the gap between freshwater lakes and those of the lower salinities studied by these authors. Particularly relevant in this context is their "Corangamite series" of lakes (which included Lakes Corangamite, Gnarpurt, Beeac, Gnotuk, Coradgill, and Kariah) because of the proximity of these lakes to Lake Modewarre and the common nature of their origins.

MATERIALS AND METHODS

The data discussed in the present study were accumulated during 36 visits to Lake Modewarre between August 1963 and September 1966. Physical and chemical observations and collections of fauna were made at approximately monthly intervals over most of this period, and three-monthly during 1966. In comparison, the data of Bayly and Williams (1966) for their Corangamite series of lakes were based mainly on a single series of faunistic collections made during March 1964 and on six series of salinity observations made at approximately three-monthly intervals between this time and July 1965.

The following data were recorded at a fixed sampling area in the north-eastern sector at approximately 1.00 p.m. on the day of each field trip to the lake: surface water temperature measured to the nearest 0.5°C; monthly maximum and minimum water temperatures, measured to the nearest 0.1°C; and water level, measured to the nearest inch from an arbitrary origin. A water sample was also taken, and a semi-quantitative plankton sample was collected by towing a plankton net just below the surface for a fixed distance between two posts. A sample of the "littoral-benthic" invertebrate fauna was collected with a dip net from amongst the vegetation in the shallows close to the shoreline, and the abundance of flying "aquatic" insects was noted. Fishes were collected with a 10 metre by 1.2 centimetre mesh seine net. The samples of plankton, littoral-benthic invertebrates, and fishes (other than *G. maculatus*, which were placed on ice and later deep-frozen) were preserved in 10% formal saline. The species of water birds present and their abundance on the lake were also noted.

TABLE 1
FLUCTUATIONS IN ENVIRONMENTAL CONDITIONS AT LAKE MODEWARRE
BETWEEN AUGUST 1963 AND SEPTEMBER 1966

Collection Date	Water Level (Inches)	Salinity (‰)	Temperature (°C)				Plankton (ml)
			Surface	Maximum	Minimum	Mean	
29. VIII. 63	—	3.70	—	—	—	—	—
24. IX. 63	—	—	—	—	—	—	—
23. X. 63	—	—	—	—	—	—	—
15. XI. 63	21	4.12	—	—	—	—	—
26. XI. 63	19	—	15.5	22.2	12.2	17.2	—
17. XII. 63	15	4.34	19.0	23.9	13.0	18.5	—
8. I. 64	9	4.50	20.0	28.3	12.2	20.3	—
4. II. 64	4	4.83	25.0	26.7	11.1	18.9	—
3. III. 64	—	4.71	—	—	—	—	—
7. IV. 64	0	4.60	16.5	24.7	7.8	16.3	—
6. V. 64	4	4.46	15.5	22.2	5.4	13.8	14
3. VI. 64	5	4.39	9.0	17.2	3.3	10.3	41
7. VII. 64	8	3.99	8.5	13.3	5.0	9.1	16
20. VII. 64	20	—	9.0	11.1	5.6	8.3	—
4. VIII. 64	26	3.80	9.5	10.8	6.1	8.5	19
18. VIII. 64	34	3.67	10.0	10.6	6.3	8.5	—
7. IX. 64	36	3.65	11.0	—	—	—	17
22. IX. 64	42	3.52	13.0	—	—	—	—
7. X. 64	46	3.45	14.0	14.4	8.3	11.3	33
5. XI. 64	57	3.22	16.5	18.3	11.7	15.0	42
2. XII. 64	56	3.16	18.0	22.0	13.9	16.9	210*
7. I. 65	52	3.45	21.0	23.3	14.7	19.0	5
5. II. 65	44	3.51	21.5	23.9	16.4	20.1	16
2. III. 65	41	3.65	25.5	25.6	21.1	23.3	5
7. IV. 65	36	3.81	18.5	20.6	11.1	15.9	3
5. V. 65	37	3.82	14.5	16.7	10.6	13.7	5
7. VII. 65	38	3.78	10.0	14.7	5.0	9.9	31
5. VIII. 65	39	3.65	8.5	16.0	6.1	11.1	9
15. IX. 65	50	3.38	13.0	20.0	11.0	15.5	30
7. X. 65	49	3.50	16.0	—	—	—	16
4. XI. 65	46	3.63	18.5	—	—	—	41
1. XII. 65	44	3.64	18.5	—	—	—	8
14. III. 66	27	4.08	21.0	—	—	—	2
8. VI. 66	26	4.19	10.5	—	—	—	16
3. VIII. 66	28	4.16	10.0	—	—	—	57
28. IX. 66	36	3.95	18.5	—	—	—	4

* Plankton bloom due to abrupt increase in population of a cladoceran, *Daphnia carinata*.

The conductivities of the water samples were measured in a constant-temperature room at 18°C using a Phillips direct-reading conductivity meter with a cell of constant 1.0. These conductivity measurements were then converted to parts per million total dissolved solids (p.p.m. T.D.S.) using a conversion coefficient of 0.675, which was calculated by evaporating known volumes of the water samples and weighing the residues. The accuracy of the conductivity method can be gauged by comparing the figure calculated by this method for February 1965 (3,560 p.p.m.) with that given by Maddocks (1967) for a sample taken from this locality during the same month of that year and calculated by summing the amounts of the different ions present (3,540 p.p.m.). For a discussion of this method for calculating the concentration of total dissolved solids see Williams (1966).

The volumes of the plankton samples were determined by allowing them to settle to constant volume in a measuring cylinder and the species present then determined by examination of sub-samples. The littoral-benthic invertebrate samples were sorted into their respective taxonomic groups and these were then listed in order of the estimated volumes of each present. The fishes were measured to the nearest 0.5 cm, length to caudal fork (LCF) being used in the case of all species except *Philypnodon grandiceps*, for which total length (TL) was used, and the condition of their gonads noted.

Mean rainfall figures for the study period were obtained from the Commonwealth Bureau of Meteorology, Melbourne.

The data accumulated on fluctuations in water level, salinity, temperature, and plankton abundance over the study period are summarised in Table 1.

RESULTS

(a) Physiography and origin

Lake Modewarre and the lakes of the "Corangamite series" studied by Bayly and Williams (1966) are situated on the eastern part of the Newer Volcanic Plain of south-western Victoria and lie within the area located between the towns of Geelong in the east and Terang in the west, Cressy in the north and Colac in the south. Lake Modewarre is the easternmost of these lakes.

Most of this plain is between 130 and 160 m above sea-level and is dotted with volcanic hills, the majority of which rise to between 50 and 100 m above the surrounding terrain. These hills are usually associated with extensive flows of olivine basalt which form a carapace over much of the area. Ollier and Joyce (1964) in a physiographic review of the region claimed that vulcanicity probably continued from earliest Pleistocene times to the Recent, and it appears that most of the lakes on these south-western plains have originated through the influence of this volcanic activity.

The basins of many of the lakes in this area appear to have been formed as a result of magma withdrawal from chambers within the crust, followed by subsidence over large areas (Hills 1959), and most of them are thus quite shallow (e.g. Lake Corangamite, the largest lake, has an average depth of between 2 and 3 m). To the west of Lake Corangamite there are several maars, some of which contain deep crater lakes (e.g. Lake Bullenmerri, c. 85 m; Lake Purrumbete, c. 50 m; Lake Gnotuk, c. 35 m). In places, lava flows have blocked river valleys and diverted river systems. Lake Modewarre appears to have been formed from part of one of these river systems, as described below.

The area between the Barwon-Leigh River system in the east and Mt. Emu Creek in the west is mainly one of endorheic (internal flowing) drainage, most of the lakes being "closed lakes" (i.e. having no outlets) and maintaining their levels primarily through the balance between winter rainfall and summer evaporation, although Maddocks (1967) has recently pointed out that the influence of ground water may also complicate this situation. These lakes are generally saline due to the gradual accumulation of salts from their inflow waters

and often exhibit large seasonal fluctuations in water level and salinity. Some of the lakes on the south-western fringe of this area, however, have outlets which overflow into nearby river systems and these are consequently "fresh" (e.g. Lake Elingamite and Lake Purrumbete).

Lake Modewarre (Fig. 1) is also a "closed lake", although it is located to the east of the Barwon River, outside the major area of endorheic drainage. This lake is situated just south

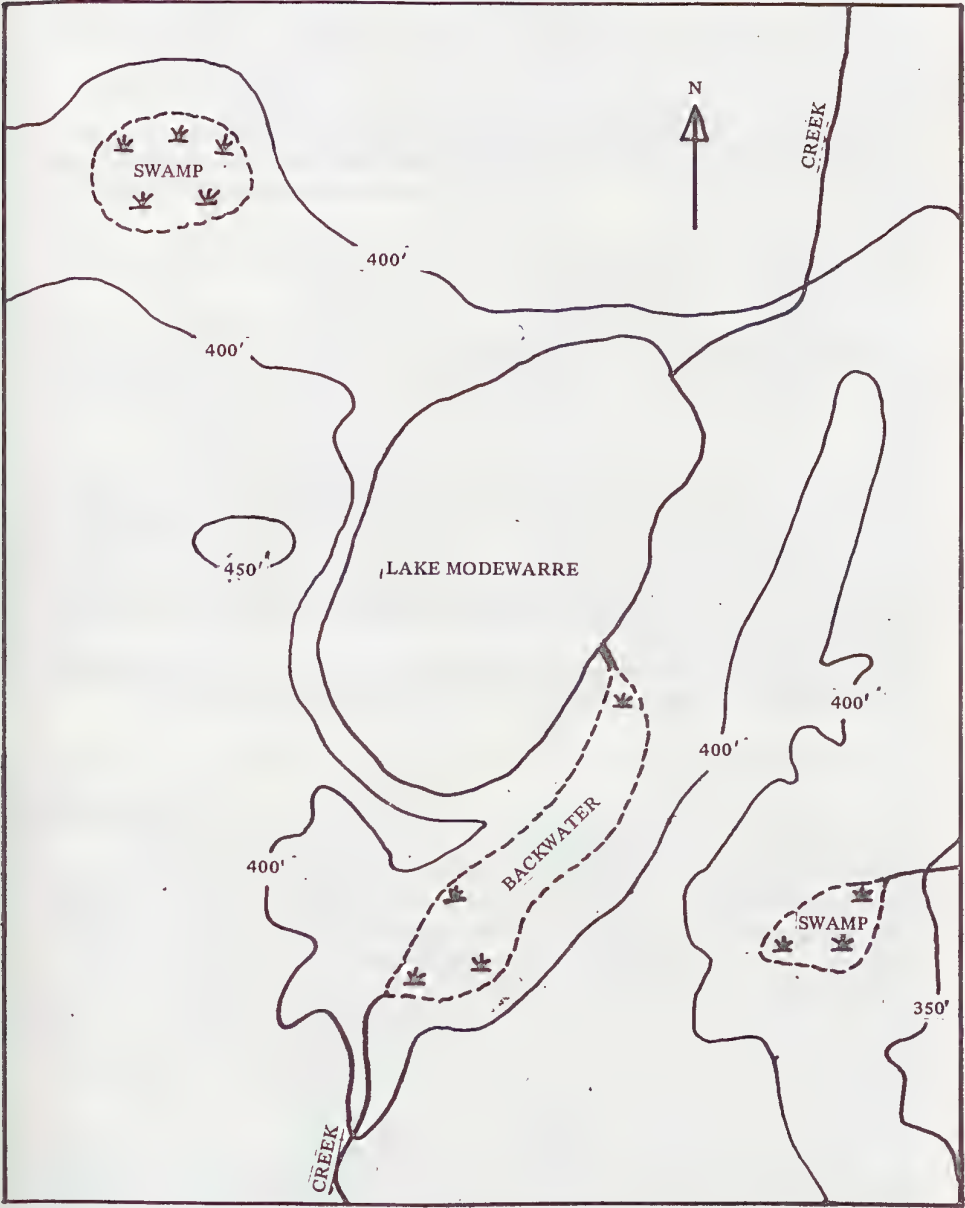


Fig. 1. Map of Lake Modewarre and surrounding area.

of the Prince's Highway near Moriac, 10 km east of Winchelsea and about 25 km west-south-west of Geelong. It covers an area of 415 ha and is located at an altitude of 120 m (approx. 375 ft.) above sea level. It is fed by two intermittent streams, one entering in the north-east and the other in the south-east. The creek to the north-east originates from a water-hole about 6 km away and its flow usually does not reach the lake except during the winter-spring high rainfall season. The creek to the south-east enters the lake via a large shallow backwater. It is also fed by run-off in the rainy season and occasionally by the overflow from the water supply channel from Wurdee Boluc Reservoir, about 6 km to the south-west.

The lake is saucer-shaped, shelving gradually to a depth of about 4 m (measured in September 1963) towards its centre. The maximum depth varied from about 3.5 (April 1964) to about 5 m (November 1964) over the study period.

The substrate consists mainly of mud containing many shells of the gastropod *Coxiella*, and large numbers of these shells form "beaches" around some parts of the shore-line. At the northernmost end of the lake there is a steep face of outcropping basalt above the rock-strewn shore.

The main physiographic changes which are thought to have taken place in the area, leading to the formation to the present lake complex, are discussed by Currey (1964), and the following brief outline is based mainly on the work of this author.

The southward flowing Leigh River and the northward flowing Barwon River, both to the east of the Corangamite area, are thought to have joined and drained to the sea through a gap close to the present position of Lake Modewarre. This outlet is thought to have been blocked by late lava flows of the Newer Basalt, diverting the river system into the Corangamite internal drainage basin to form a large lake which encompassed most of the lakes in Bayly and Williams' "Corangamite series" (with the exception of Lake Gnotuk), and also Lakes Murdeduke, Weering, Bookar, Colongulac, and Colac. This large lake eventually overflowed to the sea by the lower Barwon River near Inverleigh. With the deepening of this outlet by erosion, and its capture of the Barwon-Leigh River system, the level of the large lake area was finally reduced giving rise to the present Lake Corangamite and the complex of smaller lakes that exist in the area to-day. Lake Modewarre is thought to have been formed from part of the bed of the earlier river outlet and probably had intermittent contact with the former extended lake area.

Thus all of the above mentioned lakes, because of the common nature of their origins, may be loosely grouped into what can be called the "Lake Corangamite Complex".

(b) Climate and chemistry

Lake Modewarre is in the southern winter-rainfall area and receives an average annual rainfall of approximately 63 cm. The heaviest rains fall in the late winter and early spring (August to October) and the lightest in mid-summer (January). Table 2 shows the mean seasonal rainfall at Moriac, and the averages of the mean seasonal rainfalls at Geelong and Colac. These seasonal figures for Moriac and the combined means of Geelong and Colac are very similar, which is to be expected as Moriac is situated between the latter two towns. Since the rainfall station at Moriac was closed down some years ago the Geelong-Colac means are therefore given as approximations of the seasonal rainfall at Moriac for the period 1963 to 1966 in this table. These data suggest that the rainfall pattern in 1963, 1965, and 1966 was approximately normal, but that 1964 was an abnormally wet year, having about 40% more rain than the average for this area. The mean relative humidity in the Geelong-Colac area is highest in June (82%) and lowest in January (67%).

This pattern of high winter-spring rainfall and low summer humidity is reflected in large fluctuations in water level of the lake; e.g. about 1.6 m (5 ft) or 27% of the mean maximum depth of about 4.3m (13.5ft) between April and November 1964. The large fluctuations in the salinity of the water; e.g. about 1.6‰, or 40% of the mean salinity of about 4‰ over the

TABLE 2
MEAN SEASONAL RAINFALL AT MORIAC COMPARED WITH GEELONG –
COLAC AND SEASONAL RAINFALL AT GEELONG – COLAC FOR THE YEARS
1963 TO 1966

Season	Rainfall (mm)					
	Moriac Mean	Geelong – Colac				
		mean	1963	1964	1965	1966
Summer (Dec.–Feb.)	109	110	161	108	93	106
Autumn (Mar.–May)	144	144	137	184	167	175
Winter (June–Aug.)	190	188	206	317	208	234
Spring (Sep.–Nov.)	186	174	122	281	174	161
Annual Totals	629	616	626	890	642	676

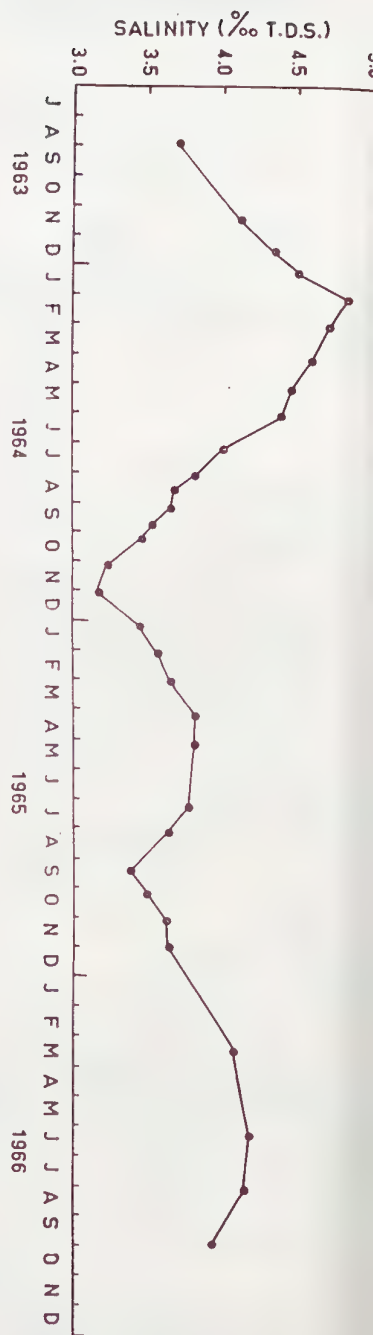


Fig. 2. Seasonal fluctuations in salinity and water level at Lake Modewarre between 1963 and 1966.

same period, are inversely proportional to changes in water level (Fig. 2). The highest water levels and lowest salinities were observed in and around late spring during each year, and the lowest water levels and highest salinities in and around late autumn. This seasonal pattern is very similar to that for Lake Corangamite, where Bayly and Williams (1966), from the recalculated data of Alexander, Sutcliffe, and Knight (1956), showed that average minimum salinities occurred in October-November and average maximum salinities in April. The highest water levels and lowest salinities observed at Lake Modewarre during the study period occurred in and around November 1964, thus correlating well with the high rainfalls recorded two or three months earlier during the same year. Bayly and Williams (op. cit., Fig. 13), from the same data mentioned above, showed a similar time lag between the periods of average maximum rainfall and average minimum salinity for Lake Corangamite.

Maddocks (1967) has suggested that the levels of Lake Corangamite and several other nearby lakes are controlled by ground water inflow coupled with solar evaporation, while those of Lake Modewarre and some of the other lakes of lesser salinity (Lakes Bolac and Colac) are controlled primarily by evaporation and run-off from their surface catchment areas. The time-lag observed between the period of highest rainfall and that of highest water-level and lowest salinity at Lake Modewarre during 1964, and its similarity in this respect to Lake Corangamite, however, may indicate that ground water also plays an important part in controlling its level.

Maddocks (1967) has recently shown that by far the greatest proportion of the dissolved salts in Lake Modewarre (about 85%) consist of sodium chloride, which he also found to be the case for the other saline lakes in the area. The ionic composition of the Lake Modewarre water sampled by Maddocks in February 1965 was as follows: Na^+ 1,100 p.p.m.; Mg^{++} 151 p.p.m.; Ca^{++} 38 p.p.m.; K^+ 12 p.p.m.; Sr^{++} 1.2 p.p.m.; Cl^- 1,940 p.p.m.; CO_3^{--} 258 p.p.m.; SO_4^{--} 33 p.p.m.; Br^- 3.8 p.p.m.; B 0.7 p.p.m.; Si 0.1 p.p.m.; N 0.1 p.p.m.; P trace. The total salinity of this water was 3,540 p.p.m. and its pH was 8.7. Bayly and Williams also analysed the ionic composition of the six lakes of their Corangamite series and found that about 85% of the cations consisted of Na^+ and 95% of the anions of Cl^- . The order of cationic dominance was $\text{Na}^+ > \text{Mg}^{++} > \text{K}^+ > \text{Ca}^{++}$, except for Lake Kariah, in which K^+ equalled Ca^{++} , and Lake Gnarpurt in which, as in Lake Modewarre, Ca^{++} was greater than K^+ .

The average salinity of Lake Modewarre water over the study period was 3,884 p.p.m. During July 1964 the salinity of the water from various parts of the creek entering the lake in the north-east, which was then flowing strongly, averaged about 200 p.p.m. Water from the backwater in the south-east, which was also flowing strongly in July 1964, contained 500 p.p.m., compared with an average of about 3,000 p.p.m. between August and October 1965, when the flow was slight or negligible. Maddocks (1967) found that the water in the water-supply channel which overflows into the creek entering this backwater had a salinity of 112 p.p.m. in February 1965.

During 1964 and 1965 the highest water temperatures were recorded between December and February and the lowest between June and August (Fig. 3). The highest monthly maximum water temperature of 28.3°C was recorded in January 1964 and the lowest monthly minimum of 3.3°C in June 1964. The mean monthly water temperature ranged from 8.3 to 23.3°C over the two years that records were kept. Bayly and Williams found that all of the lakes which they studied were subject to a similar climate, with an average annual rainfall of between 50 and 60 centimetres, and average July and January air temperatures of about 10°C and 15-21°C respectively.

(c) Fauna and flora

(i) *Rotifera*. — Two species of brachionid rotifers, *Brachionus plicatilis* Müller and *Keratella quadrata* Müller were found in the lake. Rotifers were first observed in the spring of 1964, and were most abundant in the plankton during the spring of 1965. These two

species occur commonly in saline lakes in other parts of the world, and are also found in a number of other lakes in the Corangamite area (Bayly and Williams 1966; Hussainy 1967, personal communication).

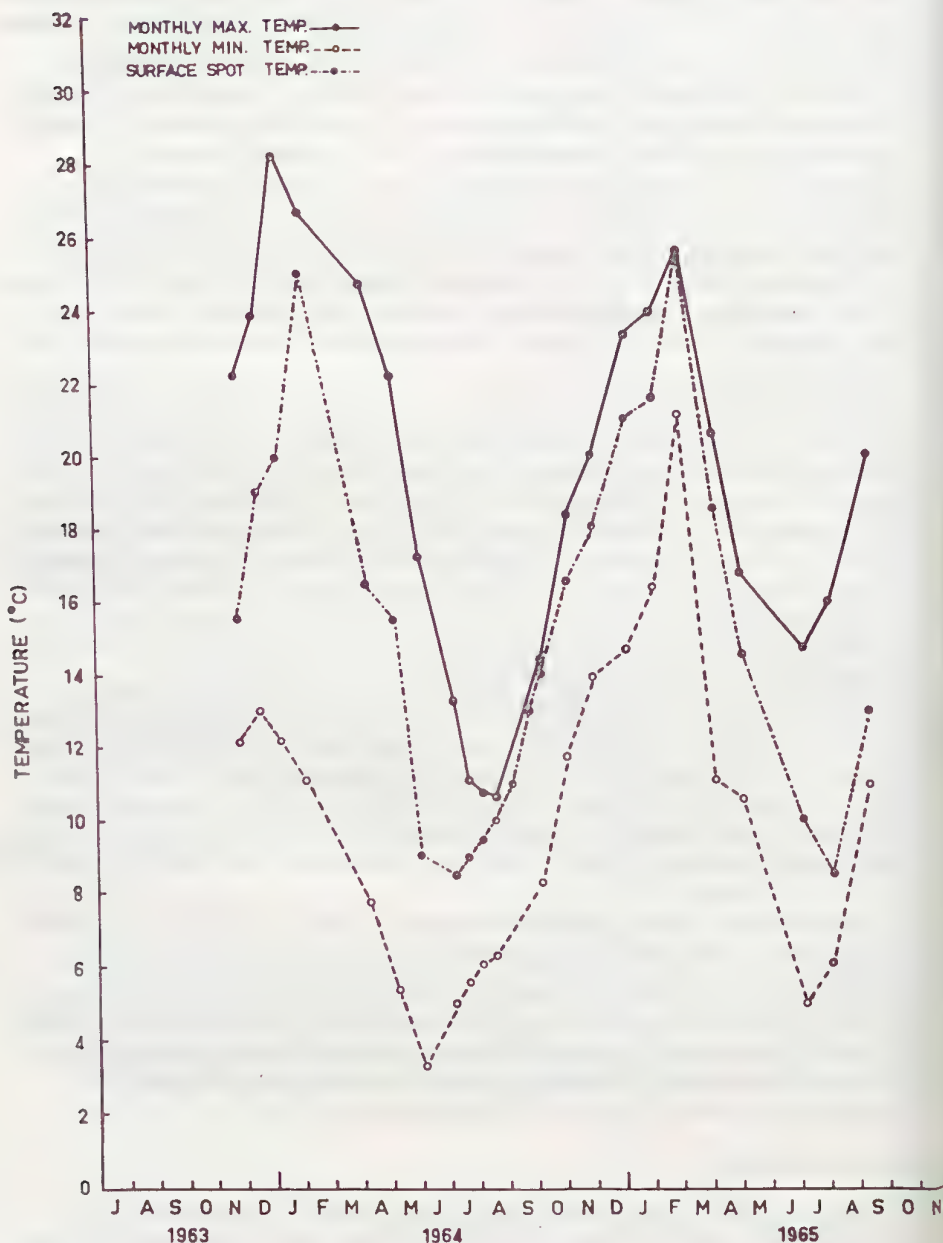


Fig. 3. Seasonal fluctuations in water temperature at Lake Modewarre between 1963 and 1965.

(ii) *Gastropoda*. — The small gastropod species *Coxiella striata* Reeve (Coxiellidae) was the only mollusc found in the lake. Live specimens were extremely common amongst the submerged vegetation and on the sediment substrate, and “beaches” consisting almost entirely of its empty shells occurred around parts of the shore-line. *Coxiella striata* is typical of saline lakes throughout south-eastern Australia and was recorded from a number of the lakes studied by Bayly and Williams. Previously, it was thought that Lake Bullenmerri with a mean salinity of about 7‰ was, “the least salt of any lakes in which this species is known to occur” (Macpherson 1957). Its occurrence in considerable abundance in Lake Modewarre (mean salinity 3.88‰ and falling to 3.16‰) thus considerably extends the recorded lower salinity tolerance of this species.

(iii) *Cladocera*. — The only cladoceran found in the lake was the planktonic species *Daphnia carinata* King (Daphniidae). This species, which was first observed in the plankton samples in spring 1964, was responsible for a spectacular plankton bloom in December of that year (see Table 1). In addition to the normal parthenogenetic females, this December sample contained large numbers of males and ephippial (fertilized sexual) females. *Daphnia carinata* was absent from the plankton samples throughout most of the following year but reappeared in December 1965. With reference to the salinity tolerance of this species Jolly (1967, personal communication) has recorded *D. thomsoni*, which she regards as a synonym of *D. carinata*, from “brackish lagoons” in New Zealand. It is interesting to note, however, that the above-mentioned cladoceran “bloom” of December 1964 coincided with the lowest salinity recorded at the lake during the study period. No cladocerans were recorded from any of the saline lakes studied by Bayly and Williams who state that; “Cladocera play no important part in the fauna of Australian athalassic saline waters of salinity greater than 10‰”.

(iv) *Ostracoda*. — The predominant ostracod species in the lake was the large littoral-benthic species *Mytilocypris henricae* (Chapman). A small species of *Cyclocypris* was also often present in the plankton, and occasional occurrences of *Iliocypris australiensis* Sars and *Cyprretta* sp. were also noted. Bayly and Williams also recorded *Mytilocypris* from several lakes in their “Corangamite series”.

(v) *Copepoda*. — The plankton of the lake was dominated at all times, except during the single cladoceran bloom mentioned above, by the calanoid copepod *Boeckella triarticulata* (Thomson). This species was also recorded as being abundant in Lake Kariah by Bayly and Williams. In addition, specimens of the benthic cyclopoid *Microcyclops australis* (Sars) were found in the stomach contents of several *Galaxias maculatus*. Bayly and Williams stated that this cyclopoid genus contains, “a number of halophilic species”, and recorded *M. arnaudi* (Sars) from Lake Beac of their “Corangamite series” at a salinity of 93.1‰.

(vi) *Amphipoda*. — The only amphipod species found in Lake Modewarre was the littoral-benthic species *Austrochilontia subtenuis* (Sayce) (Hyalellidae) which was common throughout the year, and which was also recorded from several saline lakes in the Corangamite area (at salinities ranging up to 29.1‰) by Bayly and Williams. The biology of the Lake Modewarre population of *A. subtenuis* was studied in detail by Lim (1964), who found that the maximum experimental salinity at which this species could live was 37.0‰.

(vii) *Decapoda*. — A few specimens of the crab *Halicarcinus lactusiris* (Chilton), which belongs to the predominately marine family Hymeniosomatidae, were dredged from the deeper parts of the lake. Lucas (1966, personal communication) recorded this species from nearby Lake Colac (salinity about 2‰). A single specimen of the atyid shrimp *Paratya australiensis* Kemp was also captured amongst the shoreline vegetation.

(viii) *Odonata*. — Several species of zygopterans were found in the lake, two of which were identified as *Argiolestes* sp. and *Austrolestes* sp. These were found close to the shore-line and amongst submerged vegetation in the shallows. The two species *Ischnura heterosticta* (Burmeister) and *Xanthagrion erythroneurum* Selys were also recorded from Lake Modewarre by Lim (1964). Bayly and Williams noted that; “Although Odonata have

not been reported from highly saline athalassic waters, they have frequently been reported from those of moderate salinity", and cited Tillyard (1917) as stating that some species of *Austrolestes* commonly breed in "brackish" water, and Watson (1958) as reporting the occurrence of *I. heterosticta*, "in waters of moderate salinity".

(ix) *Hemiptera*. — The commonest hemipteran in the lake was the corixid *Sigara sublaevifrons* Jaczewski, which was found around the shore-line and amongst the submerged vegetation. Another corixid, *Micronecta* sp., and a notonectid, *Anisops* sp., were also occasionally found. Lim (1964), in addition to *Sigara* sp., also recorded another notonectid, *Enithares* sp., and a naucorid, *Naucoris* sp., from this lake. Aquatic hemipterans were not, however, recorded from the saline lakes examined by Bayly and Williams, although these authors pointed out that Macan (1963) regarded corixids as being typical of the faunas of saline lakes in America, Africa, and Asia. Ettershank, Fuller, and Brough (1966) collected both corixids and notonectids from saline bore waters in western New South Wales at salinities of up to 53‰.

(x) *Diptera*. — Several species of chironomid larvae were found in the lake. These included *Chironomus australis* Macquart, *C. conjunctus* Walker, *C. alternans* Walker, and *Procladius villosimanus* Kieffer. Swarms of adult chironomids (mostly *C. australis*) were also occasionally observed (in March 1964, November 1964, and November 1965). *Procladius villosimanus* was also recorded from Lake Kariah by Bayly and Williams. With reference to the occurrence of *C. conjunctus*, *C. alternans*, and a species of *Procladius* in ephemeral pools in Western Australia, Edward (1968) stated that these Australia-wide forms can be regarded as "being opportunistic species with wide physiological tolerances".

(xi) *Trichoptera*. — The larvae of at least two species belonging to the family Leptoceridae were found close to the shore-line and in the shallows of Lake Modewarre throughout the year, and swarms of adult trichopterans were observed in November 1964 and November 1965. Bayly and Williams also found leptocerid larvae in some of the lakes which they studied, and commented that; "Trichoptera have been recorded only rarely from athalassic saline waters, and when they have the waters have always been only moderately saline". Leptocerid larvae were previously recorded from Lake Modewarre by Lim (1964).

(xii) *Lepidoptera*. — A single aquatic lepidopteran larva (*Nymphula* sp.; family Pyralidae) was collected from the lake in September 1966. Bayly and Williams, who also collected a single larva belonging to this family from one of their "Corangamite series" of lakes at a salinity of 21‰, commented that; "the Lepidoptera has relatively few aquatic members, and those that are, have all been reported from fresh waters; none are reported from athalassic saline waters". They claimed that theirs appeared to be the first record of the group from saline waters.

(xiii) *Coleoptera*. — The aquatic hydrophilid *Berosus australiae* Mulsant and the dytiscids *Bidessus* sp. and *Macropus howitti* Clark were collected close to the shore-line of the lake, but these beetles were relatively uncommon. In addition to *B. australiae*, Lim (1964) also recorded the hydrophilids *Hydrophilus latipalpus* Castelnau and *Hydrobius assimilis* Hope from this locality. Bayly and Williams noted that; "Many coleopteran genera . . . have been recorded from athalassic saline waters and the occurrence of beetles in Australian saline lakes is not therefore surprising".

(xiv) *Other Invertebrates*. — In addition to the above-mentioned groups of invertebrates, several small oligochaetes were found in the bottom sediments, numbers of water-mites (Hydracarina) were occasionally found amongst the plankton, and numbers of small isopods were observed around the shores of the lake. None of these forms, however, has been identified.

(xv) *Pisces*. — The only native fishes found in Lake Modewarre were, in order of abundance, a landlocked form of *Galaxias maculatus* (Jenyns), family Galaxiidae; a species of *Retropinna*, family Retropinnidae; and *Philypnodon grandiceps* (Kreft), family Gobiidae. In addition to these, two introduced species, *Salmo gairdneri* Richardson, family Salmonidae; and *Perca fluviatilis* Linnaeus, family Percidae, were also present. *Salmo trutta* Linnaeus had

also been introduced to the lake in the past and was recorded by Lim (1964), but none of this species were captured during the present study.

All of the above mentioned fishes, with the exception of *P. fluviatilis*, belong to the "peripheral division" of freshwater fishes, which is defined by Darlington (1957) as consisting of families which, "although found in fresh-water, are somehow closely connected with the sea or have been so recently derived from it that their present distributions may be and often are largely the result of dispersal through the sea". In contrast to these highly salt-tolerant forms, *P. fluviatilis* is a "true" or "primary division" freshwater fish (see Myers 1938 and Darlington 1957).

The Galaxiidae is a family of southern circumpolar distribution, having members in southern Australia, New Zealand, southern South America, and southern South Africa. *Galaxias maculatus*, in its normal catadromous form, is also found throughout most of the above range, but not in South Africa. The form in Lake Modewarre can be regarded as a landlocked "ecological race" of this normally catadromous species. The systematic relationship of this form to other riverine and landlocked forms included in the "*G. maculatus* species complex", and its origin from the catadromous form, are discussed in detail in Pollard (1968).

Although most members of the family dwell permanently in fresh-waters, in addition to *G. maculatus*, the catadromous habits of which have long been known, at least six other galaxiid species from New Zealand and Tasmania have more recently been shown to also have marine juvenile and migratory "whitebait" stages in their life histories (McDowall 1964, 1966a; Scott 1941; Lynch 1965).

Galaxias maculatus was found in the lake throughout the study period, but displayed considerable fluctuations in numbers at least in the study area. Galaxiids were most abundant in the spring of 1963, were relatively abundant in the autumn and spring of 1964 and again in autumn 1965, became scarce during the latter part of 1965, and were extremely scarce throughout 1966. The average length (LCF) of the 4,617 fish measured was 8.7 cm, with individual fish ranging from 2.0 to 17.5 cm. This landlocked galaxiid spawns in spring and grows to approximately 9 cm in its first, 14 cm in its second, and 17 cm in its third year of life. A number of aspects of its biology, including its food-chain relationships with the other organisms inhabiting the lake, are discussed in detail in Pollard (1968).

The Retropinnidae is an Australasian family which appears to have four euryhaline members (at least two of which are normally anadromous) and three members restricted to fresh-water in New Zealand, and three normally anadromous members in Australia. Although the specific identity of the landlocked form in Lake Modewarre has not yet been determined, it appears to be close to *Retropinna victoriae* Stokell. Retropinnids were present in almost all of the monthly fish samples from the lake, but were absent from those taken between February and August 1964. The 898 fish sampled averaged 5.0 cm in length (LCF), with a range of 2.5 to 8.0 cm. Examination of the gonad condition at different seasons showed that this species spawned in the late spring and early summer of 1964, and by following the progression of length-frequency modes it was found that fish which had hatched in about December 1964 grew to approximately 5 cm in their first year.

The eleotrine gobies are a widespread Indo-Pacific group with marine, estuarine, and fresh-water representatives in Australia and New Zealand. The genus *Philypnodon* is found in both Australia and New Zealand, but *P. grandiceps* is endemic to eastern Australia. One of the New Zealand species, *P. hubbsi* Stokell, and several members of the closely related genus *Gobiomorphus* are known to have marine juvenile stages (McDowall 1966b). Eleotrine gobies were present in most of the monthly fish samples from the lake, but were absent from the collections taken between April and August 1965. The 80 fish sampled averaged 6.0 cm in length (TL), with a range of 2.0 to 10.5 cm. Examination of the gonad condition of some of these fish indicated that this species spawned in the early spring during 1964, but no estimate of the growth rate could be made using the scanty length-frequency data available.

Both *S. gairdneri*, which is native to North America, and *S. trutta* which is native to Europe, exist as "sea-run" forms over most of their native and introduced ranges. Both have been periodically liberated for angling purposes in many western Victorian lakes, including Lake Modewarre. However, neither of these species normally reproduces in such lacustrine environments and the populations in these lakes must therefore be replenished by restocking. No *S. trutta* and only six *S. gairdneri*, were captured during the study period. Of the latter species, one of 17 cm LCF with undeveloped gonads was captured in November 1963, and the rest (three of approximately 12 cm LCF with undeveloped gonads, one ripe male of approximately 30 cm LCF, and one ripe but egg-bound female of 56 cm LCF) were captured in the late winter and early spring of 1964.

Perca fluviatilis, a native of Europe, has also been introduced to Lake Modewarre for angling purposes, but unlike the two species of trout mentioned above, reproduces freely in the lake environment. This species, which was next in abundance after *Retropinna*, was present in most of the fish samples from the lake but was absent from the collections taken between April and September 1965. The average length (LCF) of the 136 fish captured was 6.6 cm, with a range from 2.0 to 22.0 cm. Examination of the gonads showed that this species spawned in the spring, and the progression of length-frequency modes showed that fish which had hatched in the late spring or early summer of 1964 grew to approximately 12 cm in their first year.

No fishes were collected by Bayly and Williams from their "Corangamite series" of lakes, but they did collect a species of *Craterocephalus* from a small lake near Lake Eliza in south-eastern South Australia at the surprisingly high salinity of 61.9‰. This genus belongs to the predominantly marine family Atherinidae and includes a number of marine, estuarine, and freshwater species in Australia.

(xvi) *Aves*. — The water birds recorded from Lake Modewarre included the little grebe (*Podiceps ruficollis novaehollandiae*) Stephens, family Podicipedidae; the Australian pelican (*Pelecanus conspicillatus*) (Temminck), family Pelecanidae; the black cormorant (*Phalacrocorax carbo novaehollandiae*) Stephens and the pied cormorant (*P. varius*) (Gmelin), family Phalacrocoracidae; the white-faced heron (*Ardea novaehollandiae novaehollandiae*) Latham, the white-necked heron (*Ardea pacifica*) Latham, and the white egret (*Egretta alba modesta*) (Grey), family Ardeidae; the white ibis (*Threskiornis molucca strictipennis*) (Gould) and the royal spoonbill (*Platalea regia*) Gould, family Plataleidae; the black swan (*Cygnus atratus*) (Latham), family Cygnidae; the mountain duck (*Tadorna tadornoides*) (Jard. and Selby), the black duck (*Anas superciliosa superciliosa*) Gmelin, and the grey teal (*A. gibberifrons gibberifrons*) Mueller, family Anatidae; the coot (*Fulica atra australis*) Gould, family Rallidae; the spur-winged plover (*Vanellus miles novaehollandiae*) (Stephens), the red-capped dotterel (*Charadrius alexandrinus ruficapillus*) Temminck, family Charadriidae; and the silver gull (*Larus novaehollandiae novaehollandiae*) Stephens, family Laridae.

Of the above the most common species on the lake were the coot, the silver gull, and the black cormorant. Australian pelicans and black swans were also usually present, but in smaller numbers, and the other species were relatively uncommon. The heaviest concentrations of black cormorants on the lake were observed during late winter and spring in both 1965 and 1966, and the concentrations of both this species and the Australian pelican were much higher during the latter year.

(xvii) *Flora*. — The submerged vegetation of the lake consisted mainly of two angiosperms, the sea tassel *Ruppia maritima* Linn. and the water mat *Lepilaeina preissii* Lehm., both of which are typical of the flora of saline lakes. This submerged vegetation was present in thick clumps around most of the lake margin to a depth of several feet at the beginning of the study period, but most of it was torn from the bottom and washed onto the shore during rough weather in the winter of 1964. Regrowth began during 1965, but the vegetation had not reached its original density by the end of the study period (September 1966). In the summer months a dense mat of filamentous green algae appeared around the shore-line of

the lake, in the isolated pools of the creek to the north-east and over the shallow banks opposite its mouth, and in the shallows of the backwater in the south-east. No collections of phytoplankton were made during the present study, but Bayly and Williams reported the alga *Nodularia spumigena* Mertens occurring in great abundance in Lake Corangamite and commented that this species is commonly found in saline lakes.

DISCUSSION

Before discussing the faunistic results of the present study it is instructive to make some quantitative observations on the distributions of the aquatic organisms recorded by Bayly and Williams (1966) within the three series of saline lakes which they studied. Of the 35 forms which they list (op. cit., Tables 13 and 14), 25 were recorded from their "Corangamite series", 20 from their "Beachport-Robe series", and 3 from their "Centre Lake series". Of these, 10 forms were common to both the "Corangamite" and "Beachport-Robe series", 3 forms to both the "Corangamite" and "Centre Lake series", 2 forms to both the "Beachport-Robe" and "Centre Lake series", and 2 forms to all three series.

Within the "Corangamite series", the individual lakes each contained between 3 (12%) and 6 (24%) of the total of 25 forms present in common with other lakes in the same series. Of the total of 39 forms comprising those found in Lake Modewarre during the present study and in the lakes of the "Corangamite series" by Bayly and Williams, 8 (approximately 20%), were common to both Lake Modewarre and some of the "Corangamite series" lakes. Only two forms (4.5%) were found to be common to both Lake Modewarre and the "Beachport-Robe series", and 1 form (2.5%) to both Lake Modewarre and the "Centre Lake series". It would thus appear that although the faunas of the three series of lakes studied by Bayly and Williams are basically similar, the fauna of Lake Modewarre shows most affinity to that of the nearby "Corangamite series". This finding is hardly surprising when the proximity of these lakes and their common origin are taken into account. The groups observed to be common to the faunas of Lake Modewarre and individual lakes in the "Corangamite series" are shown in Table 3, in which the lakes are arranged in order of increasing average salinity.* Thus Lakes Coradgill and Kariah, the least saline of the "Corangamite series", each contain 6 forms (15.4% of the total of 39) in common with Lake Modewarre, Lake Gnarpurt contains 4 (10.3%), Lake Corangamite 3 (6.9%), Lake Gnotuk 1 (2.6%), and Lake Beeac, the most saline, none. However, Bayly and Williams no doubt overlooked a number of other forms which are probably also common to the faunas of Lake Modewarre and at least some of the lakes of their "Corangamite series".

* With regard to the salinity differences between the various lakes it should be noted that both Lakes Coradgill and Kariah, although having a much higher average salinity than Lake Modewarre, occasionally fall, due to their greater salinity variations, into the salinity range observed for the latter lake — as was observed in the spring and summer of 1964 by Bayly and Williams (op. cit., fig. 8.)

In this regard it can be seen from Table 3 that those forms which were observed to occur in both Lake Modewarre and various lakes of the Corangamite series included mainly forms noted as very common (i.e. *Coxiella striata*, *Mytilocypris* sp., *Boeckella triarticulata*, *Austrochiltonia subtenuis*, and *Leptoceridae*) in the former lake, together with a few noted as seasonally occurring (*Brachionus plicatilis*), occasional (*Procladius villosimanus*), or in one case very rare (Pyralidae). Of the other forms noted as very common or common in Lake Modewarre, *Galaxias maculatus*, although not recorded by Bayly and Williams, is known to occur in Lake Corangamite and also in several other lakes in the same region, including Lake Colongulac (salinity 8.3‰), Lake Colac (salinity 1.9‰), and Wurdee Boluc Reservoir (fresh?) The salinities are for samples taken in February 1965 by Maddocks (1967).

TABLE 3
FAUNAL COMPARISON OF LAKE MODEWARRE AND LAKES OF THE
CORANGAMITE SERIES

Aquatic Organisms Recorded from Lake Modewarre	Lake Modewarre	Lake Coradgill	Lake Karah	Lake Gnapurt	Lake Corangamite	Lake Gnotuk	Lake Beac
ROTIFERA							
Brachionus plicatilis	SO(?)	X	X	X	X	-	-
Keratella quadrata	SO(?)	-	-	-	-	-	-
GASTROPODA							
Coxiella striata	VC	X	X	X*	X*	X*	-
CLADOCERA							
Daphnia carinata	SA	-	-	-	-	-	-
OSTRACODA							
Mytilocypris sp.	VC	X	X	X	-	-	-
Cyclocypris sp.	C	-	-	-	-	-	-
Iliocypris australiensis	O	-	-	-	-	-	-
Cypretta sp.	O	-	-	-	-	-	-
COPEPODA							
Boeckella triarticulata	VC	-	X	-	-	-	-
Microcyclops australis	VR(?)	-	-	-	-	-	-
AMPHIPODA							
Austrochiltonia subtenuis	VC	X	X	X	X	-	-
DECAPODA							
Halicarcinus lacustris	R	-	-	-	-	-	-
Paratya australiensis	VR	-	-	-	-	-	-
ODONATA							
Argiolestes sp.	R	-	-	-	-	-	-
Austrolestes sp.	R	-	-	-	-	-	-
HEMIPTERA							
Sigara sublaevifrons	VC	-	-	-	-	-	-
Micronecta sp.	O	-	-	-	-	-	-
Anisops sp.	O	-	-	-	-	-	-
DIPTERA							
Chironomus australis	O	-	-	-	-	-	-
Chironomus conjunctus	VC	-	-	-	-	-	-
Chironomus alternans	O	-	-	-	-	-	-
Procladius villosimanus	O	-	X	-	-	-	-
TRICHOPTERA							
Leptoceridae	VC	X	-	-	-	-	-
LEPIDOPTERA							
Pyalidae	VR	X	-	-	-	-	-
COLEOPTERA							
Berosus australiae	R	-	-	-	-	-	-
Bidessus sp.	R	-	-	-	-	-	-
Macropus howitti	R	-	-	-	-	-	-
PISCES							
Galaxias maculatus	VC	-	-	-	-	-	-
Retropinna sp.	VC	-	-	-	-	-	-
Phlypnodon grandiceps	C	-	-	-	-	-	-

Symbols and abbreviations: - X = present; - = not collected; * = empty shells only; VC = very common; C = common; O = occasional; R = rare; VR = very rare; SA = seasonally abundant; SO = seasonally occurring.

The other two fishes present in Lake Modewarre (*Retropinna* sp. and *Philypnodon grandiceps*) are probably also present in at least some of these other lakes. The insects *Sigara sublaevis* and *Chironomus australis*, due to their size and relative abundance in Lake Modewarre, probably would not have been overlooked had they been present in any numbers in the lakes studied by Bayly and Williams, although the ostracod *Cyclocypris* sp., due to its extremely small size, could easily have been missed.

Of the remaining forms, those noted as occasional, rare, or very rare in Lake Modewarre, because of their rarity, might have been overlooked had they occurred in any of the lakes of the "Corangamite series". Two other species were noted as either seasonally occurring or seasonally abundant in Lake Modewarre. Of these, the rotifer *Keratella quadrata*, although not recorded by Bayly and Williams, was found to be common in a number of the saline lakes in the Corangamite area by Hussainy (1967, personal communication). The remaining form noted as seasonally abundant in Lake Modewarre was the cladoceran *Daphnia carinata*. The seasonal appearance of this species illustrates another factor which must be taken into account when the faunas of athalassic lakes of different salinities are compared; i.e. the possibility of seasonal or occasional reappearances of forms with relatively low salinity tolerance when the waters of these lakes fall to a suitable salinity level. *Daphnia carinata* was most abundant in Lake Modewarre during the period of lowest observed salinity (December 1964), reappeared again at about the same time in the following year, but was not found in the lake when its salinity was greater than 3.65‰. The relatively high proportion of males and of females carrying sexually fertilized, resistant, ephippial eggs, probably accounts for its ability to reappear seasonally in great abundance. This example emphasises the need for regular sampling throughout the year if meaningful faunal comparisons are to be made.

The data presented in Table 3, in spite of these inadequacies, do indicate a rough correlation between the concurrence of different elements in the faunas of these lakes and their respective average salinities. Such a gradual fall off in concurrence with increasing salinity is to be expected when it is considered that the great majority of these organisms, as was indeed the case for most of the other forms collected by Bayly and Williams, are of definite fresh-water affinities. Probably the only exceptions in the Lake Modewarre fauna are the gastropod *Coxiella striata*, a member of a family apparently closely related to the marine Truncatellidae, and which Bayly and Williams thought had "colonised" the saline lake habitat via a marine littoral-marine supralittoral-terrestrial-athalassic supralittoral pathway; the crab *Halicarcinus lacustris*, which belongs to a marine-estuarine genus and family; and the three fishes *Galaxias maculatus*, *Retropinna* sp., and *Philypnodon grandiceps*, all of which belong to families having members which either live in or enter the sea.

It would thus appear that any clear division of athalassic lake habitats into "fresh" or "saline" based upon faunistic criteria, at least for these lakes in south-eastern Australia, would be quite artificial. Similar studies on some of the "fresher" lakes of the Lake Corangamite Complex (e.g. Lake Colac, salinity approximately 2‰; Lake Purrumbete, salinity approximately 0.4‰; and Wurdee Buluc Reservoir, fresh?) should provide further information of interest in this context.

ACKNOWLEDGMENTS

The author would like to acknowledge the assistance of the many specialists who helped him by identifying or checking his identifications of various species belonging to the following invertebrate groups. These workers included Dr. I.A.E. Bayly (Copepoda), Dr. W.D. Williams (Amphipoda), Dr. I.D. Hiscock (Gastropoda), and Mr. S.U. Hussainy (Rotifera), all of the Department of Zoology and Comparative Physiology, Monash University; Dr. K.G. McKenzie (Ostracoda), formerly of the same institution and now at the British Museum (Natural History), London; Dr. V.H. Jolly (Cladocera), of the Metropolitan Water Sewerage and Drainage Board, Sydney; Mr. J. Lucas (Decapoda) and Dr. D.H. Edward (Diptera), both of the Department of Zoology, University of Western Australia; and Mr. A. Neboiss (Insecta,

excluding Diptera), of the National Museum of Victoria, Melbourne. I would particularly like to thank Drs. I.A.E. Bayly, K.G. McKenzie and W.D. Williams, and also Dr. P.H. Greenwood of the British Museum (Natural History), for their comments on and constructive criticism of the manuscript.

References

- ALEXANDER, G.N., SUTCLIFFE, A.G., and KNIGHT, R.G. (1956). — Preliminary hydrologic investigation of Lake Corangamite floodings. First Progress Report. State Rivers and Water Supply Commission, Melbourne, Victoria. (Roneoed.)
- BAYLY, I.A.E., and WILLIAMS, W.D. (1966). — Chemical and biological studies on some saline lakes of south-east Australia. *Aust. J. mar. Freshwat. Res.* 17, 177-228.
- CURREY, D.T. (1964). — The former extent of Lake Corangamite. *Proc. R. Soc. Vict.* 77, 377-86.
- DARLINGTON, P.J. (1957). — "Zoogeography; the Geographical Distribution of Animals". Wiley: New York.
- EDWARD, D.H. (1968). — Chironomidae in temporary freshwaters. *Aust. Soc. Limnol. Newsl.* 6(1), 3-5.
- ETTERSHANK, G., FULLER, M., and BROUGH, E.J. (1966). — Hemiptera from saline waters in inland Australia. *Aust. J. Sci.* 29, 144-5.
- HILLS, E.S. (1959). — "Physiography of Victoria". Whitcombe & Tombs: Sydney & Melbourne.
- LIM, K.H. (1964). — The biology of *Austrochiltonia subtenuis* (Sayce) 1902. M. Sc. Thesis, Department of Zoology and Comparative Physiology, Monash University, Victoria.
- LYNCH, D.D. (1965). — Changes in Tasmanian (whitebait) fishery. *Fish. Newsl.* 24 (4), 13-5.
- MACAN, T.T. (1963). — "Freshwater Ecology." Longmans, Green: London.
- MACPHERSON, J.H. (1957). — A review of the genus *Coxiella* Smith, 1894, *sensu lato*. *West. Aust. Nat.* 5, 191-204.
- MADDOCKS, G.E. (1967). — The geochemistry of surface waters in the western district of Victoria. *Aust. J. mar. Freshwat. Res.* 18, 35-52.
- MCDOWALL, R.M. (1964). — A consideration of the question "what are whitebait?". *Tuatara* 12, 134-46.
- MCDOWALL, R.M. (1966a). — Further observations on *Galaxias* whitebait and their relation to the distribution of the Galaxiidae. *Tuatara* 14, 12-18.
- MCDOWALL, R.M. (1966b). — A guide to the identification of New Zealand freshwater fishes. *Tuatara* 14, 89-104.
- MYERS, G.S. (1938). — Freshwater fishes and West Indian zoogeography. *Smithsonian Rep.* 1937, 339-64.
- OLLIER, C.D., and JOYCE, E.B. (1964). — Volcanic physiography of the western plains of Victoria. *Proc. R. Soc. Vict.* 77, 357-76.
- POLLARD, D.A. (1968). — The biology of a landlocked form of the teleost fish *Galaxias attenuatus* (Galaxiidae) with special reference to reproduction. Ph. D. Thesis, Department of Zoology and Comparative Physiology, Monash University, Victoria. (In preparation for publication.)
- SCOTT, E.O. (1941). — Observations on fishes of the family Galaxiidae. III. *Pap. Proc. R. Soc. Tasm.* 1940, 55-69.
- TILLYARD, R.J. (1917). — "The Biology of Dragonflies (Odonata or Paraneuroptera)." Cambridge University Press.
- WATSON, J.A. (1958). — The Odonata of south-western Australia. Honours Thesis, Department of Zoology, University of Western Australia.
- WILLIAMS, W.D. (1966). — Conductivity and the concentration of total dissolved solids in Australian lakes. *Aust. J. mar. Freshwat. Res.* 17, 169-76.

OFFICE BEARERS 1971-1972

PRESIDENT

D. D. Francois, B.Sc., M.Sc., Ph.D.
Director, New South Wales State Fisheries,
211 Kent Street,
Sydney, N.S.W. 2000.

VICE PRESIDENT

N. M. Morrissy, B.Sc. (Hons.), Ph.D.
Department of Fisheries and Fauna,
Western Australian Marine Research Laboratories,
North Beach, W.A. 6020.

SECRETARY-TREASURER

D. A. Pollard, B.Sc. (Hons.), Ph.D.
New South Wales State Fisheries,
211 Kent Street,
Sydney, N.S.W. 2000.

COMMITTEE MEMBERS

I. D. Hiscock (Vic.) (ex-officio)	S. H. Midgley (Qld.)
L. M. Angel (S.A.)	I. J. Powling (Vic.)
J. S. Lake (N.S.W.)	I. C. Smalls (N.S.W.)
L. C. Llewellyn (N.S.W.)	R. D. Tilzey (N.S.W.)
D. D. Lynch (Tas.)	

EDITORIAL BOARD

I. D. Hiscock (Chairman)	D. D. Francois
D. A. Pollard (Bulletin Editor)	I. J. Powling
B. J. Smith (Newsletter Editor)	I. C. Smalls
	R. D. Tilzey

NEWSLETTER EDITOR

Dr. B. J. Smith,
National Museum of Victoria,
285-321 Russell Street,
Melbourne, Vic. 3000.

LIBRARIAN

Mr. A. L. Dyce,
McMaster Animal Health Laboratories,
Private Bag No. 1,
Glebe, N.S.W. 2037

AUDITOR

Mr. I.C. Smalls,
Metropolitan Water, Sewerage and Drainage Board,
Post Office Box No. 2,
Guildford, N.S.W. 2161.

Note: Please address all general and editorial correspondence and manuscripts to the Secretary-Treasurer. Newsletter correspondence should be addressed to the Newsletter Editor, and reprints sent to the Librarian.

